VOL. XLV JANUARY 1961 NO. 1

THE JOURNAL OF AGRICULTURE

of the

UNIVERSITY OF PUERTO RICO

UNIVERSITY OF NEBRASKA AGRICULTURAL LIBRARY APR 20 1961

INOCULATION OF SUGARCANE PLANTS WITH THE MOSAIC VIRUS USING THE AIRBRUSH.....*Julio Bird* 1

FURTHER STUDIES ON TRANSMISSION OF THE CAUSAL AGENT OF THE CHLOROTIC-STREAK DISEASE OF SUGARCANE.....*Julio Bird* 8

COEFFICIENT OF FRICTION, ANGLE OF REPOSE, SPECIFIC GRAVITY, AND BULK DENSITY OF COFFEE FRUITS AND COFFEE BEANS
Adolfo Eschenwald and Carl W. Hall 19

SNAP BEAN-VARIETY TRIALS AT THE LAJAS SUBSTATION
Oscar D. Ramínez and José A. Quiñones 26

BEEF PRODUCTION AND CARRYING CAPACITY OF HEAVILY FERTILIZED, IRRIGATED GUINEA, NAPIER, AND PANGOLA GRASS PASTURES ON THE SEMIARID SOUTH COAST OF PUERTO RICO
Rubén Caro-Costas, José Vicente-Chandler, and Calvin Burleigh 32

EFFECTS OF NITROGEN FERTILIZATION AND FREQUENCY OF CUTTING ON THE YIELD AND COMPOSITION OF PANGOLA GRASS IN PUERTO RICO..*José Vicente-Chandler, Jacinto Figarella, and Servando Silva* 37

EFFECTS OF TWO CUTTING HEIGHTS ON YIELDS OF FIVE TROPICAL GRASSES.....*Rubén Caro-Costas and José Vicente-Chandler* 46

EVALUATION OF THE AVERELL AND NORRIS METHODS FOR THE DETERMINATION OF PARATHION IN WEST INDIAN CHERRY (*Malpighia punicifolia*, L.).....*Gilberto García Monge* 50

PUBLISHED BY
UNIVERSITY OF PUERTO RICO
AGRICULTURAL EXPERIMENT STATION
RÍO PIEDRAS, P. R.

Second-class postage paid at Río Piedras, under the Act of August 24, 1912, as amended by the Act of August 4, 1947.

University of Puerto Rico

AGRICULTURAL EXPERIMENT STATION

Río Piedras, Puerto Rico

JAIME BENÍTEZ, M.A., Ll.M., Chancellor

Station Staff[1]

Arturo Roque, M.S. ..... *Director*
B. G. Capó, Ph.D. ..... *Associate Director*
A. González Chapel, M.S. ..... *Assistant Director*
M. A. Lugo López, Ph.D. ..... *Assistant Director*

Agricultural Economics and Rural Sociology

J. M. Ríos, M.S., Rural Sociologist, Head of Department
M. Avilés Cordero, M.S., Economist
R. Calero, B.A., Research Assistant
J. B. Candelas, M.A., Assistant Economist
A. L. Caraballo, M.A., Research Assistant
J. Collazo Collazo, M.A., Assistant Sociologist
L. R. Collazo Sainz, B.A., Assistant Sociologist
R. García Ortega, B.A., Research Assistant
A. Guzmán (Miss), B.A., Research Assistant
D. Haddock Suárez, M.B.A., Economist
L. Hernández, M.S., Assistant Economist
A. Lloréns, M.S., Assistant Economist
J. L. Maldonado, B.A., Research Assistant
J. A. Molina Mercado, B.S., Research Assistant
R. Pedraza, B.A., Assistant Economist
G. E. Pringle, M.A., Research Assistant
J. L. Quintero Alfaro, B.A., Research Assistant
B. Rodríguez (Mrs.), B.A., Research Assistant
O. Rodríguez García, B.A., Research Assistant
L. Rodríguez de Zapata (Mrs.), B.A., Research Assistant
E. Silva, M.S., Economist and Budget Analist
R. M. Silva de Bonilla (Mrs.), B.A., Research Assistant
S. Torres Román[3], B.B.A., Research Assistant
D. Vargas Hernández, M.A., Research Assistant
J. Zapata, B.A., Research Assistant

Agricultural Engineering

J. H. Rodríguez Arias, Ph.D., Professor of Agricultural Engineering, Head of Department
R. Otero Dávila[3], B.S., Research Assistant

Agronomy and Horticulture

P. González Ríos[3], M.S., Agronomist, Head of Department
E. Alsina[4], B.S., Agricultural Aid
S. Alers Alers, B.S., Assistant Agronomist
A. S. Amy, B.S., Associate Agronomist
E. Boneta[4], M.S., Agronomist
A. G. Colón, B.S., Assistant Agronomist
H. Gandía Díaz, B.S., Horticulturist
F. González Vélez, B.S., Research Assistant
E. Hernández Medina, Ph.D., Horticulturist
G. Maldonado Marty, B.S., Research Assistant
N. Márquez Lugo, B.S., Assistant Agronomist
F. Méndez Roig, M.S., Agronomist
W. Pennock, M.S., Horticulturist
J. P. Rodríguez, B.S., Agronomist
G. Samuels, Ph.D., Agronomist

Animal Husbandry

L. Rivera Brenes, Ph.D., Animal Husbandman, Head of Department
H. Arrillaga, B.S., Research Assistant
J. A. Arroyo, B.S., Assistant Biochemist
C. M. Berrocal, M.S., Assistant Bacteriologist
H. Cestero, B.S., Associate Animal Husbandman
W. L. Comstock, M.S., Associate Animal Husbandman
J. C. López Alberty, B.S., Research Assistant
C. R. Peebles, Ph.D., Associate Parasitologist
J. D. Rivera Anaya, V.M.D., Veterinarian

Entomology

L. F. Martorell, Ph.D., Entomologist, Head of Department
A. Ayala Almodóvar, M.S., Research Assistant
E. A. Jordán, B.S., Research Assistant
S. Medina Gaud[3], B.S., Research Assistant
M. E. Pérez Escolar, Ph.D., Entomologist
C. T. Ramírez (Miss), B.S., Research Assistant
J. Román Toro, M.S., Research Assistant
G. Steiner, Ph.D., Nematologist

Food Technology Laboratory

F. Sánchez Nieva, M.S., Technical Director
J. Anziani (Mrs.), B.S., Research Assistant
J. R. Benero, B.S., Assistant Chemist
L. E. Cancel[3], B.S., Assistant Chemist
L. A. Carlo Vélez, B.S., Research Assistant
G. Colom Covas, B.S., Assistant Horticulturist
J. R. Cruz Cay, B.S., Research Assistant
E. Díaz (Miss), B.S., Research Assistant
N. Díaz (Miss), B.S., Research Assistant
B. Galanes (Mrs.), M.S., Research Assistant
A. García (Miss), B.S., Research Assistant
J. R. García (Mrs.), B.S., Research Assistant
M. A. González, M.S., Assistant Chemical Engineer
I. Hernández Vizcarrondo, B.S., Research Assistant
M. Martínez[2] (Mrs.), B.S., Research Assistant
M. Matos Maldonado, B.S., Research Assistant
A. R. Rahman, Ph.D., Associate Food Technologist
A. J. Rodríguez, B.S., Associate Chemical Engineer
A. Román (Miss), B.S., Research Assistant
R. Vázquez Romero, B.S., Assistant Chemical Engineer

Plant Breeding

J. Vélez Fortuño, Ph.D., Plant Breeder, Head of Department
H. Azzam, Ph.D., Associate Plant Breeder
C. García Rodríguez[2] (Miss), B.S., Research Assistant
H. Irizarry, B.S., Research Assistant
O. D. Ramírez, M.S., Assistant Plant Breeder
T. Singh, Ph.D., Associate Plant Breeder
A. Sotomayor Ríos, M.S., Research Assistant
R. Woodbury, M.S., Taxonomist

Phytopathology and Botany

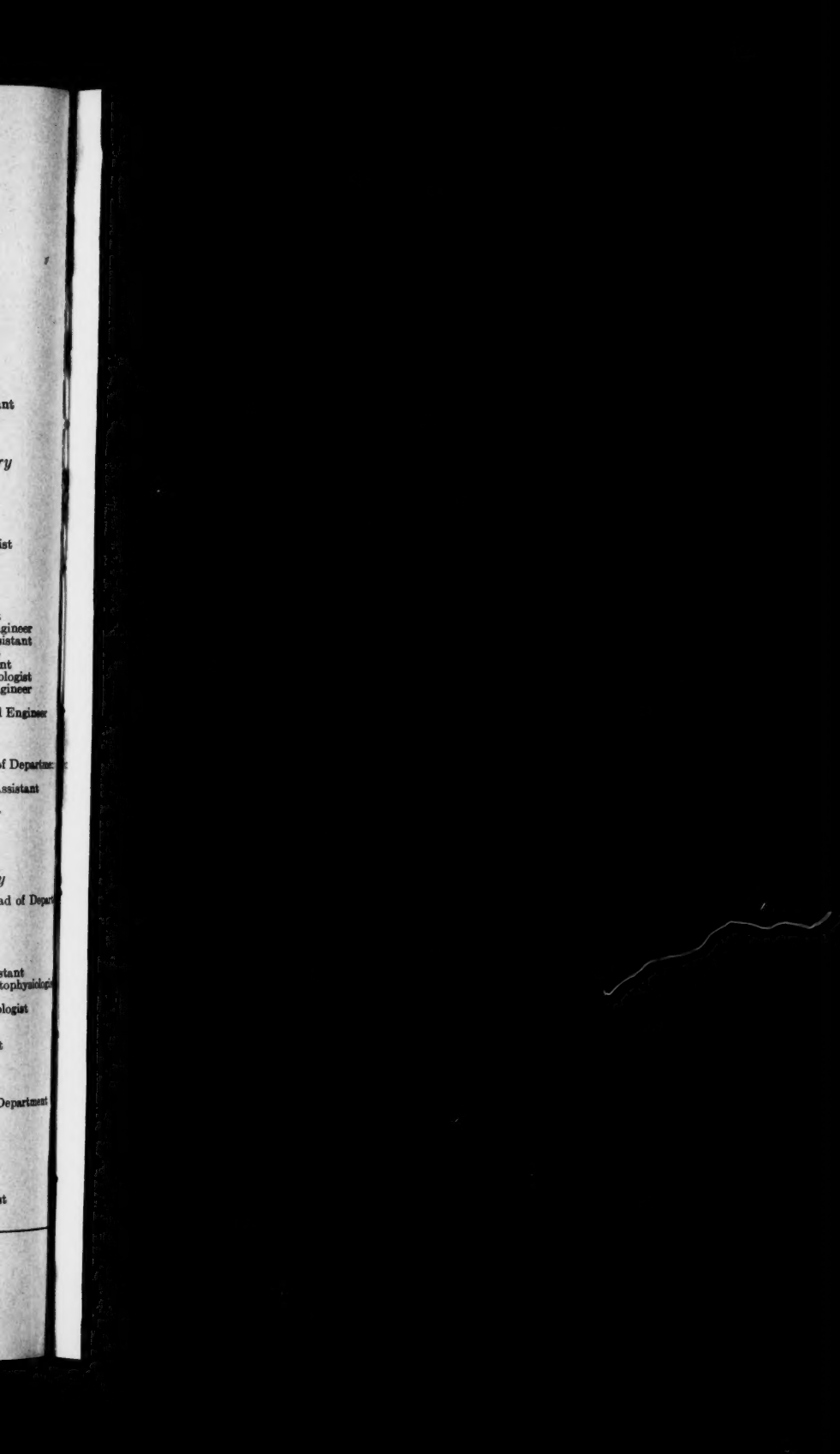
F. L. Wellman, Ph.D., Phytopathologist, Head of Department
J. Adsuar Miró, B.S., Phytopathologist
L. A. Alvarez[2], M.S., Phytopathologist
J. Bird Piñero, Ph.D., Phytopathologist
H. Cibes Viadé, Ph.D., Phytophysiologist
A. Cortés Monllor (Mrs.), B.S., Research Assistant
M. C. Fernández (Mrs.), Ph.G., Assistant Phytophysiologist
J. González Ibáñez, B.S., Research Assistant
J. H. López Rosa, M.S., Assistant Phytopathologist
J. E. Pérez Otero, Ph.D., Bacteriologist
A. Sánchez Miranda, B.S., Research Assistant
M. A. Tió, Ph.D., Associate Phytophysiologist

Soils

J. A. Bonnet, Ph.D., Soil Scientist, Head of Department
G. Acevedo Ramos, M.S., Research Assistant
E. J. Brenes, M.S., Assistant Soil Scientist
R. A. Canals, B.S., Research Assistant
W. Francia Rivera, B.S., Research Assistant
G. García Monge, M.S., Research Assistant
J. Juárez, Jr., B.S., Assistant Soil Scientist
M. A. Negrón[3], B.S., Research Assistant
R. Pérez Escolar[3], M.S., Assistant Soil Scientist
J. Roldán Regus, M.S., Assistant Chemist

[1] As of July 1, 1960.
[2] On other types of leaves.
[3] On leave to pursue studies.
[4] USDA collaborators.

(Continued on inside back cover)



THE JOURNAL OF AGRICULTURE
OF THE UNIVERSITY OF PUERTO RICO

Issued quarterly by the Agricultural Experiment Station of the University of Puerto Rico, for the publication of articles by members of its personnel, or others, dealing with any of the more technical aspects of scientific agriculture in Puerto Rico or the Caribbean Area.

Vol XLV January 1961 No. 1

Inoculation of Sugarcane Plants with the Mosaic Virus Using the Airbrush

Julio Bird[1]

INTRODUCTION AND REVIEW OF THE LITERATURE

Several mechanical methods are conventionally utilized to inoculate sugarcane plants with the causal agent of its common mosaic disease. According to Matz (*5*)[2] Kammerling, working in Java, claimed in 1903 that he had succeeded in transmitting the disease by injecting healthy sugarcane plants with sap expressed from affected ones. However, according to Matz, Kammerling's claim was invalidated by the fact that some uninoculated control plants also contracted the malady. In 1920 Brandes (*1*) transmitted the etiologic agent of the mosaic disease by injecting sap from infected plants into the growing points of healthy ones by means of a hypodermic syringe.

A somewhat different method was employed in Cuba by Bruner (*2*) who successfully transmitted the virus in 1922. This was achieved by superimposing affected upon healthy leaves and rapidly thrusting a fine hypodermic needle through the infected leaf into the healthy one. In 1930 Seín (*6*) devised a technique similar to the one employed by Bruner. Seín effected his inoculations with No. 0 or No. 2 insect pins and obtained high percentages of infection. Seín (*7*) also obtained infection by pricking in juices pressed out from mosaic tissues into the leaves of healthy plants. This was accomplished by smearing the leaves with inoculum and subsequently stabbing them repeatedly with an insect pin.

In 1933 Matz (*5*) published the results of his work on the artificial transmission of sugarcane mosaic and developed a new technique which was a refinement of the previous pin-thrust methods. In this latest technique a few drops of infective sap are placed in the wedge-shaped opening formed by the base of the youngest expanded leaf and the young rolled leaf. Re-

[1] Plant Pathologist, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P.R.

The writer wishes to express his appreciation to José Adsuar, Héctor Cibes, and Ferdinand Méndez, Río Piedras, P.R., for their disinterested help during the course of this work.

[2] Italic numbers in parentheses refer to Literature Cited, p. 7.

peated thrusts are then practiced through the inoculum reservoir and into the young rolled leaf. Edgerton (*3*) mentioned a technique by means of which young sugarcane plants from true seed can readily be infected with the mosaic. The leaves of the young plants are merely clipped and then the seedbeds are sprayed with virus-containing juice from affected plants. The common method of inoculating plants by rubbing their leaves with virus-containing juices in the presence of carborundum is also employed to infect sugarcane plants with mosaic. This method is fairly efficient when dealing with seedling plants, but awkward, inefficient, and cumbersome for larger plants.

The Matz or pin-thrust method has been used regularly in Puerto Rico for a number of years because it results in higher rates of infection than those produced by the earlier manual techniques. Be that as it may, the Matz method is still cumbersome, and time-consuming, and also requires a certain skill for best results.

OBJECTIVES

Bearing in mind the inconveniences of the Matz method, it was decided to undertake work in an attempt to determine whether the airbrush method, devised by Lindner and Kirkpatrick in 1959 (*4*), could be successfully adapted to inoculate sugarcane plants with the common mosaic virus, and, if so, to evaluate an adaptation of the Lindner and Kirkpatrick method by comparing it in parallel inoculation tests with the standard Matz method.

MATERIALS AND METHODS

SPRAY EQUIPMENT

A Paasche "H 3-in-1" airbrush coupled to a 3-ounce glass bottle was used throughout the inoculation trials. The source of compressed air was a 1-hp. twin-piston industrial sprayer with a 12-gallon air storage tank. This unit was provided with a pressure switch to start the motor at 75 pounds per square inch, and to stop it at 100 pounds. The line pressure was maintained at 75 pounds with an air regulator which was connected to a filter unit capable of removing oil, water, and foreign matter. For inoculation, the flow-control tip on the Paasche airbrush was adjusted by revolving it clockwise 1½ turns from the close-setting. This setting was used throughout all of the trials.

INOCULUM

Leaves from severely affected plants of different varieties were used as sources of inoculum. Upon collection the leaves were rinsed with tapwater, chopped with scissors, and ground with the aid of a precooled Universal

meat grinder No. 73. The juice from the ground leaves was then expressed using a Carver laboratory press. In all cases the macerated leaves were subjected to a pressure of 5,000 pounds per square inch for maximum juice yield. After extraction every batch of juice was agitated and immediately divided into two equal volumes. Carborundum (600-mesh) was added at the rate of 1 gm. per 100 cc. to the inoculum that was to be used for the airbrush method. No carborundum was added to the inoculum destined for the Matz method.

TEST PLANTS

The sugarcane plant varieties B. 34104, P.O.J. 2878, P.R. 980, H. 328560, and B.H. 10(12) were used in the inoculation trials. The varieties B. 34104, and B.H. 10(12) are known to be very susceptible to mosaic under natural conditions in Puerto Rico. They have also been shown to be very susceptible when inoculated by artificial means. In Puerto Rico the varieties P.R. 980 and H. 328560 have been found less susceptible than the former under natural conditions and rather hard to infect by artificial means. As far as is known there have been no observations in Puerto Rico of an infected cane plant of the variety P.O.J. 2878 in the field. A few instances of infection of plants of this variety via the Matz method have been recorded by Adsuar in the Island. Apparently, the variety is refractory to infection when inoculated by pin-thrust methods.

The test plants were grown from one-eyed seedpieces. The canes from which the seedpieces originated were in all cases obtained from mosaic-free plants in the Experiment Station's collection. Immediately after the canes were reduced to one-eyed-seedpiece size they were separately treated with phenyl mercuric acetate (500 cc. per gallon of water) and then planted in flats containing a mixture of clay loam, sand, and filter-press cake. All plants germinated normally except those belonging to the variety B.H. 10(12). On pulling and observing some of these plants no roots were detected at the root bands of the seedpieces. These plants recovered when roots began to spring from their bases. Inoculations using the two means under evaluation were effected 22 days after the seedpieces were planted. In general, at the time of inoculation, the plants had attained a height which varied from 7 to 14 inches.

INOCULATION PROCEDURE

A group of plants was inoculated via the Matz method as described previously. A set of plants of each variety was left undisturbed as an uninoculated control. The following procedure was effected in inoculating plants via the airbrush method: The two youngest leaves of the plant to be inoculated were held as depicted in figure 1, and the aircap of the atomizer was

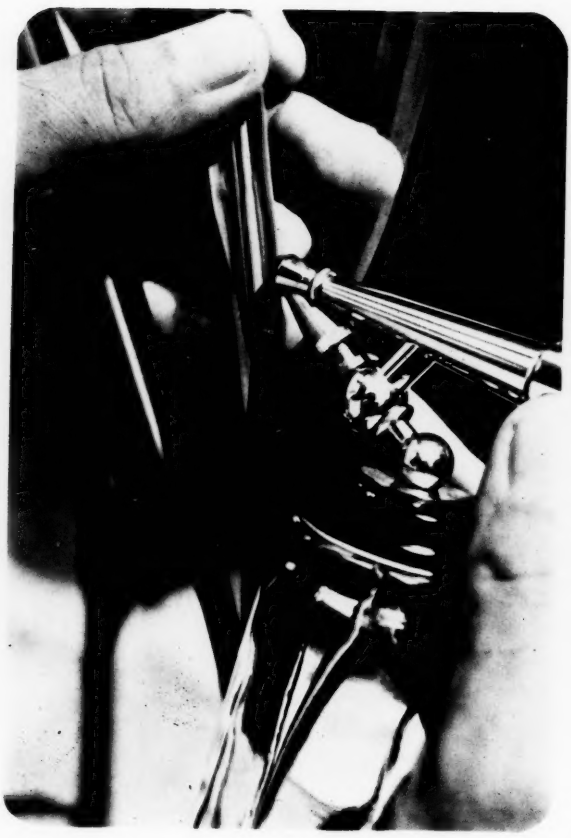


FIG. 1.—Manner in which the airbrush was used on the youngest leaves of sugarcane plants for inoculation purposes.

brought perpendicularly to rest on the unfurled leaf's upper surface at a height of about $1\frac{1}{2}$ inches from the spindle. Spraying began at this site. While still pressing the release lever the aircap was quickly drawn downwards, but in contact with the unfurled leaf until the tender base tissues of the selected leaves were reached, and then was speedily brought upwards to the starting site by the same route. This procedure was repeated until about six passes were completed.

This technique was found to be the least awkward and produced excellent results. Attempts to set distances from the nozzle to the leaf surfaces by various small mechanical devices complicated the procedure and were postponed for later studies. By applying the aircap to the leaf surfaces as indicated a distance of about 0.5 cm. was found at most times to separate the surface of the youngest expanded leaf from the tip of the aircap; possibly the distance was shorter during most of the operation. The entire procedure of inoculating a plant via the airbrush took at the most 4 seconds by one man as against 10 seconds employed by two men using the Matz method. Consumption of inoculum was about the same in both cases. Inoculations via the Matz and airbrush methods were started simultaneously in the two first tests herein reported.

EXPERIMENTAL RESULTS

As a rule, symptoms began developing 10 days after the plants were inoculated via the airbrush. This was not true for plants inoculated by the Matz method, in which symptoms first became noticeable about 12 days after inoculation. The final results of the tests reported in table 1 were recorded 1 month after inoculation. The airbrush-inoculated plants of the P.O.J. 2878 variety are of particular interest since such high incidence of disease was not expected to occur. To study the behavior of affected P.O.J. 2878 plants, 46 of them were marked and observed further. Forty-four days after inoculation 20 of these plants still manifested severe symptoms of disease in all their leaves. Of these 20 plants, 3 were almost totally necrotic and about to die. The course of the symptoms was dissimilar in the remaining 26 plants; the top three leaves of these were completely devoid of symptoms 44 days after inoculation. The plants that appeared to recover are still being observed and studied.

More successful inoculations by both the Matz and the airbrush method were expected in the case of the variety B.H. 10(12). Although planted at the same time as the rest of the varieties in test No. 2, its germination was very poor and for a time its growth was very stunted. About 2 weeks after germination, and prior to inoculation, more than 80 percent of these plants became wilted and developed terminal burning of the youngest leaf. At the time of inoculation the plants of this particular variety were still

visibly affected. Possibly higher rates of infection by both methods of inoculation might have resulted had the B.H. 10(12) plants been healthier.

DISCUSSION

The high incidence of mosaic in plants of the variety P.O.J. 2878 when inoculated via the airbrush was unexpected because this cane had been relatively resistant to mosaic when inoculated by the older methods. As far as is known this variety has not been found infected in the fields of the Island. As mentioned previously, the variety P.O.J. 2878 is apparently

TABLE 1.—*Number and percentage of successful inoculations of healthy sugarcane plants of several varieties in tests designed to compare the efficiency of the standard Matz method with that of the airbrush method*

Test No.	Varieties	Number of plants infected by the Matz and the airbrush methods over plants treated by each method, and percentage infection[1]			
		Matz method		Airbrush method	
		Infected/ treated	Percentage infection	Infected/ treated	Percentage infection
1	P.O.J. 2878	3/162	1.8	56/137	40.8
	H. 328560	3/127	2.4	19/348	5.5
2	P.O.J. 2878	0/156	0	52/134	38.8
	H. 328560	0/140	0	26/150	17.3
	P.R. 980	0/148	0	9/133	6.8
	B. 34104	45/142	31.6	67/118	56.8
	B.H. 10(12)	21/105	20.0	30/97	30.9

[1] For each treatment a set of 25 uninoculated plants of each variety was set aside as a control. None of these plants became affected.

capable of "recovering" from the disease. However, much more work is needed on this before a definite conclusion can be reached. At any rate the "recovery" phenomenon could, in part, explain the complete absence of mosaic on the variety P.O.J. 2878 under our conditions. It is possible that other factors such as preferences of the aphid vectors might also be responsible for the absence of mosaic in Puerto Rican fields planted to the variety P.O.J. 2878.

To some it may seem that the airbrush method of inoculation is undesirable because, by means of it, the so-called "immune" variety P.O.J. 2878 has been consistently and easily infected. As mentioned earlier, even before the introduction of the airbrush method several instances of successful pin-thrust inoculation of plants of P.O.J. 2878 had been recorded by Adsuar in Puerto Rico. During the late stages of these studies claims were made by

some that the Uba variety, commonly known to be immune, would, like the variety P.O.J. 2878, contract mosaic if and when inoculated by the airbrush.

To clarify these questions 100 Uba (immune to mosaic) and 100 M. 336 (susceptible to mosaic) plants were inoculated by the airbrush with infective sap obtained from mosaic plants. Twenty-five plants of each variety were set apart as uninoculated controls. All inoculated plants of the variety M. 336 developed symptoms of mosaic; not one of the similarly treated plants of the Uba variety did so. The control plants remained healthy. It is believed that these results clearly demonstrate that the airbrush method is simply a more efficient method of inoculation, but not one capable of infecting immune plants.

The airbrush method is not affected by several of the variables which usually produce inconsistencies in the results of inoculation by the older methods. In this method the impelling force is air, the pressure of which can be satisfactorily regulated. The flow of inoculum and abrasive can also be so regulated that comparatively little variation should result.

SUMMARY

The results of the studies reported herein show that the airbrush method is more easily used and more efficient in infecting sugarcane plants with the common mosaic virus than the standard Matz pin-thrust method.

RESUMEN

Los resultados de estos trabajos demuestran que el método, en el cual se utiliza un pincel de aire, es más eficiente que el método de Matz para inocular plantas de caña de azúcar con el mosaico común de esta cosecha.

LITERATURE CITED

1. Brandes, E. W., Artificial and insect transmission of sugarcane mosaic, *J. Agr. Res.* **19** 131–8, 1920.
2. Bruner, S. C., Sobre la transmisión de la enfermedad de "mosaico" o "rayas amarillas" en la caña de azúcar, *Rev. Agr.*, Com. y Trab. (Cuba) **5** 11–22, 1922.
3. Edgerton, C. W., Sugarcane and its Diseases, Louisiana State University Press, Baton Rouge, La., 2nd rev. ed., 1959.
4. Lindner, R. C., and Kirkpatrick, H. C., The airbrush as a tool in virus inoculations, *Phytopath.* **49** 507–9, 1959.
5. Matz, Julius, Artificial transmission of sugarcane mosaic, *J. Agr. Res.* **46** 821–40, 1933.
6. Sein, Jr., Francisco, A new mechanical method for artificially transmitting sugarcane mosaic, *J. Dept. Agr. P. R.*, **14** 49–68, 1930.
7. ——, Artificial Transmission and other Studies on Sugarcane Mosaic, Int. Soc. Sugar Cane Tech., Proc. 4th Cong. (1932), Bul. 84, 1932.

Further Studies on Transmission of the Causal Agent of the Chlorotic-Streak Disease of Sugarcane

Julio Bird[1]

INTRODUCTION AND REVIEW OF THE LITERATURE

Several investigators (*1*, *4*, *6*, *13*, *14*)[2] from different parts of the world have effected transmission of the causal agent of the chlorotic-streak disease of sugarcane by growing together diseased and healthy plants in jars containing nutrient solution. Evidence was presented by Bird, Cibes, and Tió (*6*) to prove that the transmission of the causal agent from diseased to healthy plants can be effected by circulation of the nutrient solution in the absence of direct root contact. These findings were recently confirmed by Abbott (*1*) in Louisiana and by Sturgess (*17*) in Australia. Boneta (*7*) observed in Puerto Rico high incidence of chlorotic streak in fields containing sugarcane seedlings. These fields were located in a high-rainfall valley near the town of Gurabo. In one case it was observed that the symptoms developed almost simultaneously throughout a field of 6-month-old seedlings. Abbott (*1*) grew diseased and healthy plants together in soil with high moisture but obtained no transmission of the causal agent by this means. Antoine (*4*), working in Mauritius, obtained evidence indicative of soil transmission when a healthy cutting became diseased after it was planted in soil which had supported the growth of an affected plant. Transmission was also effected when a healthy, heat-treated cutting was transferred to unsterilized soil from a diseased area.

OBJECTIVES

The rapid development of chlorotic-streak disease in a moist field planted to sugarcane seedlings suggests not only that the spread of the causal agent is carried out by water but is also soil-borne. It was decided to undertake work in an effort to determine whether, under our conditions, the causal agent of chlorotic streak is transmitted through the soil.

It was also thought advisable to determine whether the causal agent could be transmitted by growing diseased and healthy plants together in water-drenched sand. The possibility of infecting healthy sugarcane plants by mechanical inoculation of their roots was also investigated. Another of

[1] Phytopathologist, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P.R. The writer is indebted to Héctor Cibes, Marco A. Tió, Frederick L. Wellman, and Jaime González for their valuable help during the course of these studies.

[2] Italic numbers in parentheses refer to Literature Cited, p. 18.

the writer's goals was to study the relation of the streak disease of Napier grass (*Pennisetum purpureum* Shumac) to the chlorotic-streak disease of sugarcane.

TRANSMISSION STUDIES

All of the sugarcane plants used in these studies were grown from one-eyed seedpieces of the highly susceptible variety H. 328560 (fig. 1A). The healthy seedpieces were obtained from presumably disease-free areas, hot-water treated (52.5° C. for 25 minutes), immediately cooled with tapwater and then submerged in a P.M.A.[3] solution for 5 minutes. After these treatments, the seedpieces were planted in galvanized-steel or in wooden flats (14″ x 20″ x 4½″) containing white quartz sand. The flats as well as the sand had been previously steam-sterilized.

The one-eyed seedpieces from which the stock of diseased plants was obtained came from severely diseased field canes. These seedpieces were treated with P.M.A. only prior to planting in the sterilized white sand.

The heat treatment used in these studies is indeed a rigorous one, but it was resorted to as an added margin of safety, even though the standard hot-water treatment is adequate to destroy the causal agent in the seedpieces. Except for the soil-transmission trial carried out in the field all the tests described in this report were conducted in screened greenhouses. In addition, the plants maintained in the greenhouse were sprayed every 2 weeks alternately with Parathion and Endrin.

TRANSMISSION THROUGH WATER-DRENCHED SAND

Trials were carried out to determine whether the causal agent would spread from diseased to healthy sugarcane plants if these were grown together in sand with an excess of water. Six sand flats containing about 15 healthy plants each were transferred and placed side by side on a new Durotex[4] greenhouse bench (96″ x 48″ x 6″). Four flats, each containing about 10 diseased plants, were placed in the remaining space. A gap of about 6 inches was left between the flats containing the two groups of plants. Fertilizer (6-12-6) was sprinkled lightly on the sand flats at the beginning of the test and also later at the time the plants were cut back.

At first the bench was flooded daily and water was slowly lost through its seams but eventually sand as well as algae and mosses prevented water from seeping through. After some 6 weeks, water was applied only about once a week in order to keep the sand drenched. After 3 months growth all the plants were cut back and allowed to ratoon. Fifteen days after the cut-back procedure was effected, most of the shoots produced by the previously

[3] Phenyl mercuric acetate, 1:1600.

[4] Asbestos cement.

healthy specimens were found to be diseased. A few ratoons were observed to be free from symptoms and these were located on the edge farthest from the area containing the disease-source plants.

After 4½ months all the shoots produced by the previously healthy plants were found to be diseased. Very few of the shoots produced by the originally diseased plants survived. Two flats containing 20 healthy plants and kept in the same greenhouse but on a separate bench remained healthy. The results of this test confirmed the findings of different investigators with respect to the role played by water in the spread of the chlorotic-streak disease. These results as well as those of previous tests indicate either that the agent causing this malady, or its vector, if any, is capable of being spread by water. Indications from these tests are also that if an aquatic vector exists it may be small enough to escape visual observation. If in this test as well as in previous tests conducted in nutrient solution in Puerto Rico a vector was involved, it must be not only small, but rather abundant under varying conditions, or else capable of remaining in the diseased seed-pieces.

It is of interest to mention at this time that various species of nematodes[5] (*Diplogaster*, *Aphelencoides*, *Panagrolaimus*, *Rhabditis*, and *Eucephalobus*) obtained from nutrient solution on which diseased canes were growing were used in extensive replicated inoculation studies covering a period of many months. The nematodes failed to induce disease on healthy plants to which they were transferred in great numbers. While this does not necessarily signify that nematodes are not associated with this disease it is, however, an indication that the nematode species mentioned are not involved in its causation or spread.

TRANSMISSION THROUGH SOIL

Greenhouse Experiments Using Field Soil as Source of Causal Agent

In the first test eight soil samples from around and beneath eight severely affected plants growing in the field were separately transferred to 10-inch pots. Four of these units were steam-sterilized while four were left undisturbed. A total of 16 plants, each about 8 inches in height, and which originated from healthy heat- and P.M.A.-treated one-eyed seedpieces, were distributed equally among the pots. The pots were then set on 8-inch porcelain pans and placed on two different flat, greenhouse benches according to treatment. The two benches were separated from each other by about 3 feet. Enough water to maintain the pans full to their brims was added daily to each pot.

The development of the plants growing in the unsterilized soil was

[5] Kindly isolated and identified by Dr. G. Steiner and associates.

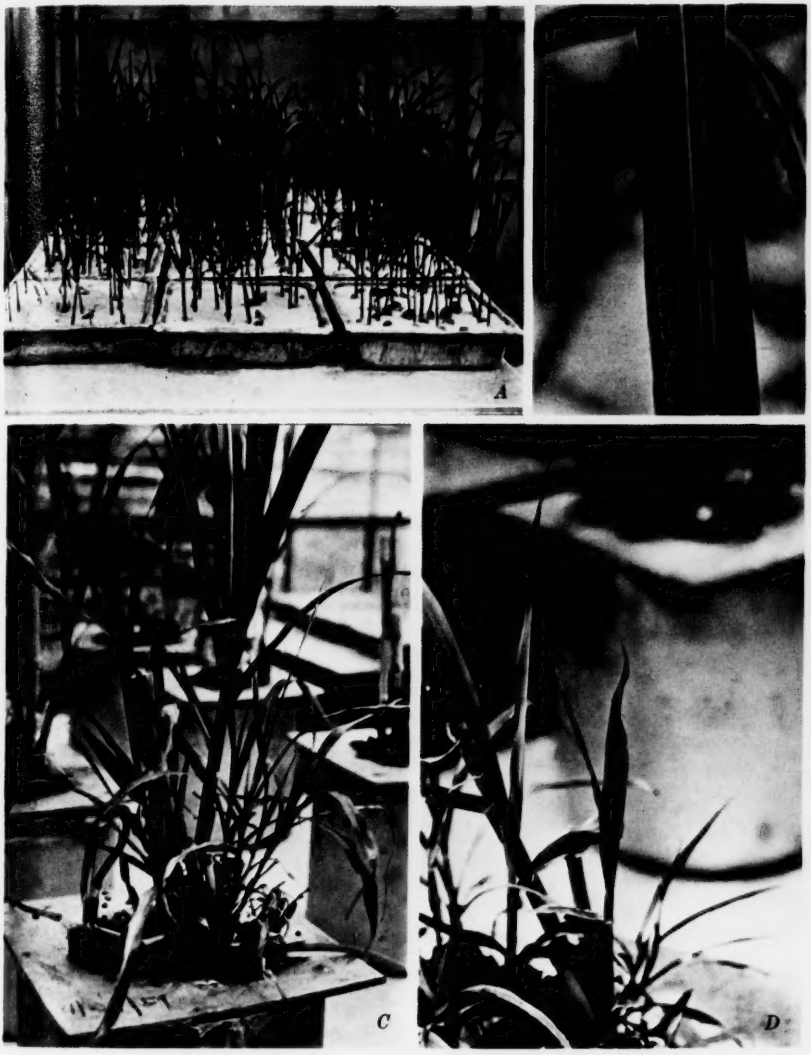


FIG. 1. — *A*, Healthy sugarcane plants of the variety H. 328560 growing on galvanized steel flats containing white quartz sand. *B*, Typical chlorotic streak on a leaf of a H. 328560 plant that contracted the disease when grown in soil from diseased areas. *C*, Napier grass and sugarcane plants growing together in jars containing nutrient solution. *D*, Initial symptoms of chlorotic streak on young sugarcane shoots growing together with affected Napier grass plants.

stunted and their leaves were observed to be chlorotic about 3 weeks after transplanting. The healthy control plants in the sterilized soil grew visibly faster and their color was strikingly greener than that of the plants growing in the untreated soil. Two spoonfuls of 6-12-6 fertilizer were added to each one of the pots of both treatments 1 month after the onset of the test. Three months after the trial was commenced, two of the plants (mother plants) growing in a pot in the unsterilized soil, developed severe symptoms of chlorotic streak. At this time none of the plants growing in the untreated soil had produced secondary shoots, while all of those in the sterilized soil had.

A week after the primary symptoms were observed the treated and the control plants were cut back with separate pruning shears to about 4 inches from the soil level. Symptoms typical of the chlorotic-streak disease were evident 15 days later on six shoots that grew from the base of the two plants that first became affected (fig. 1B).

All the control plants remained healthy. A further control, consisting of hundreds of healthy stock plants which were kept in the same greenhouse where the study was being made, also failed to develop symptoms of the streak disease. The plants in the pots containing the undisturbed soil were pulled out and immediately replaced with 16 healthy plants at a rate of 4 per pot. The plants in the originally steamed soil were also replaced with healthy specimens. Five months elapsed and since no symptoms could be observed on any of the plants they were all cut back and allowed to ratoon. Thirty days after the canes were cut back symptoms of chlorotic streak developed on one shoot. On identifying the pot it was verified that it was the one where the earlier cases of disease had developed. The pots were maintained in the greenhouse for two more months and no further cases of chlorotic streak developed in either of the two treatments.

A more extensive test on soil transmission was effected using the same type of materials as well as procedure employed in the first phase of the previous trial. This time 60 healthy plants were equally distributed among 30 pots containing unsterilized soil from field sources. Another batch consisting of 100 healthy control plants was similarly distributed among new pots containing steam-sterilized soil from the same origin. Two months after the onset of the test one of the plants growing in a pot containing unsteamed soil from the field developed severe symptoms of chlorotic streak. Neither its companion plant nor the rest of the plants in both treatments had developed symptoms of chlorotic streak 3 months after the test was commenced. At this stage all the plants were cut back and shoots allowed to develop. One shoot that grew from the base of the affected cane as well as one that arose from the base of its companion plant, developed severe symptoms of chlorotic streak and then died. Two more cases of chlorotic

streak appeared in two shoots belonging to two other different pot units in the unsterilized soil treatment. No instances of disease developed among the control plants. Many of the plants growing in the unsteamed soil produced ratoons which died before unfurling their leaves. The writer assumes that in all probability some of these would have developed chlorotic-streak symptoms had their growth progressed further. That this assumption is probably correct is evidenced by the results of the following test on the germinability of chlorotic-streak-affected seedpieces as compared with that of chlorotic-streak-free ones.

Presumably healthy as well as chlorotic-streak-affected canes obtained from the same general locality were placed in different burlap bags after being cut down to approximately 2 feet-long-pieces. The presumably healthy seedpieces were heat-treated (52.5° C. for 25 minutes), cooled with tap-water, and placed on a greenhouse bench that was contiguous to one where the diseased seedpieces were kept. The affected as well as the healthy cane pieces were then cut down to one-eyed seedpiece size by two individuals and simultaneously immersed in different crocks containing P.M.A. solution (1:500). The solutions were decanted and the one-eyed seedpieces of both treatments separately planted in galvanized-steel flats containing steamed white quartz sand.

A total of 141 seedpieces was planted for each treatment. Approximately 82 percent of the healthy seedpieces produced shoots the leaves of which had unfurled at the end of 30 days while only 34 percent of the diseased seedpieces had done so after the same length of time. Forty-two of the diseased seedpieces produced roots at the root band and their eyes began to germinate, but this incipient growth became stunted and eventually the partly germinated buds died. It is possible, thus, that in the extensive test on soil transmission previously reported many cases of chlorotic streak went undetected because of premature death of the shoots due to the effects of the causal agent of chlorotic streak.

Field Experiment

An attempt was made to transmit the causal agent of the chlorotic-streak disease by growing affected and healthy sugarcane plants in alternate blocks in a gently sloped area in the field. The small plot (20′ x 36′) used for this experiment had not been grown to sugarcane for at least 5 years. The experiment was arranged so that run-off rainwater would move by gravity through the alternate blocks of plants and finally come to rest on a diked section occupied by rows of healthy plants. A large number of healthy control plants was provided and grown above the alternate blocks, and separated from the slope by a buffer space of about 6 feet. This particular experiment was situated about 50 yards away from a commercial field

where chlorotic streak was known to be extremely abundant and still spreading. All the plants in this test were allowed to grow undisturbed for 10 months at which time a disease count was made.

A single healthy test plant developed symptoms of chlorotic streak under the conditions of this test. This plant belonged to the first row of a block of healthy plants that was situated below a row of affected plants. Although the results were not significant from the standpoint of spread of the disease through the soil, they were nevertheless interesting if absence of aerial transmission is to be considered. If leafhoppers were at least partly involved in the transmission of chlorotic streak under our conditions more cases of disease should have resulted throughout the numerous healthy plants in this particular test. All the test plants were cut back at the 10th month of growth and allowed to ratoon. No other cases of disease were observed 6 months after the cut-back procedure was effected.

TRANSMISSION OF CHLOROTIC STREAK FROM NAPIER GRASS TO SUGARCANE PLANTS

Napier grass is grown extensively in Puerto Rico for cattle feed. In 1953, Bruehl (*8*) described a streak disease of this grass and made observations on the similarity of that disease to the chlorotic-streak disease of sugarcane. Bruehl (*8*), and Bruehl and Boneta (*9*) were able to render Napier grass seedpieces free of the disease by treatment with hot water (52° C. × 20 minutes). The similarity of the symptoms of the disease on Napier grass to those on sugarcane, as well as the fact that the aforementioned heat treatment destroyed the causal agent in both hosts, prompted Bruehl and Boneta to postulate that this disease of Napier grass was caused by the same agent responsible for the streak disease of sugarcane.

A test using nutrient solution as a growing medium was made by the writer in an effort to transmit the causal agent from streak-diseased Napier grass to sugarcane plants. Sixteen Napier grass plants from a severely diseased field were taken to the greenhouse and their main stems pruned down to about 2 inches of height. The plants were washed several times with a jet of filtered water to free the roots from soil and were then set in pairs on 5-gallon aluminum-painted Pyrex crocks containing nutrient solution of the same type used in previous studies (*6*). The plants were also supported in the same manner as before (fig. 1 C). A total of eight jars, each containing two plants, was then set on a flat Durotex bench. Two days later, 16 sugarcane plants about 8 inches in height were obtained from the stock of healthy plants growing in the same greenhouse and were distributed equally among the jars where the diseased Napier plants were already growing. A control consisting of 16 healthy sugarcane plants growing in nutrient solution was set on a different bench in the same greenhouse. Again numerous

healthy plants were maintained as control stock in the same greenhouse. The nutrient solution in the jars was replenished as needed and replaced every month.

Four months after the trial was set up, one of the sugarcane plants in one of the test units developed typical symptoms of chlorotic streak. At this stage all the plants were cut back and allowed to ratoon. Five and a half months after the test was started, transmission had been effected in four out of the eight test units. Nine sugarcane shoots out of a total of 22 produced by the test plants, developed symptoms of disease at this time. None of the controls or of the healthy-stock plants in the same greenhouse developed the malady. The symptoms on the test sugarcane plants in all cases were identical with those that are considered typical for the chlorotic-streak disease of this host (fig. 1D).

FAILURE OF TRANSMISSION BY MECHANICAL MEANS

From the indications of all of our tests, as well as from the results reported by other investigators, the causal agent of the chlorotic-streak disease of sugarcane gains access to the plants through their root systems. Having this in mind, attempts were made to transfer the etiologic agent by inoculating the roots of healthy plants with extracts from roots of affected ones. The roots and lower parts of 16 small healthy plants were washed free of sand and the plants temporarily set in a sterilized, stainless-steel beaker containing filtered tapwater. Roots from diseased plants growing in nutrient solution were macerated in a Waring Blendor and the resulting suspension sprinkled with carborundum and stirred. The roots of the healthy plants were rubbed vigorously with this mixture and then the plants were transferred to pots containing sterilized soil. The plants were kept at high moisture for about 5 months and then cut back. None of these plants or their shoots became diseased in any respect after 6½ months. An equal number of healthy controls planted in sterilized soil also failed to develop symptoms of chlorotic streak.

DISCUSSION

The results of the study on soil transmission of chlorotic streak are in agreement with the findings of Antoine in Mauritius. The tests on soil transmission carried out in Puerto Rico were carefully controlled and it is most unlikely that any other agent not brought in with the unsterilized field soil was responsible for the cases of disease.

It seems likely that, under field conditions in Puerto Rico, the causal agent of the chlorotic-streak disease of sugarcane is transmitted mainly if not solely from the roots of affected to those of healthy plants through the soil. The available evidence suggests that high soil moisture is extremely

important not only for the expression of the symptoms of the disease, but for the spread of its causal agent. At present, the prevailing theory is that this malady of sugarcane is caused by a virus.

While the leafhopper *Draeculacephala portola* Ball was reported by Abbott and Ingram (*2*) to be the vector of chlorotic streak in the State of Louisiana, so far as is known, others have not made successful studies to confirm or disprove these findings of Abbott and Ingram. Although the available scientific evidence strongly indicates that a virus is responsible for this disturbance, it seems reasonable not to disregard the seemingly remote possibility that it might be caused by another entity.

With respect to this, Carpenter (*10*) in Hawaii reported evidence that a Chytrid-like organism was in strict association with the tissues of affected sugarcane plants. Abbott and Sass (*3*), working in Louisiana, also observed the bodies that Carpenter interpreted as stages of the life cycle of a Chytrid, in the tissues of affected plants. However, these last workers believed that the various bodies exhibiting some degree of structural organization were probably the metabolic products of the affected plants rather than etiologic agents.

The fact that the causal agent of the chlorotic-streak disease is soil-transmitted would not necessarily exclude a virus as the possible entity responsible for this malady since other viruses have been found to be transmitted through the soil. Bawden (*5*) listed the causal agents of tobacco mosaic, wheat mosaics, lettuce big-vein, and tobacco necrosis as belonging to this group of soil-borne viruses. According to him, the stability of tobacco mosaic is such that it would be expected to remain infective in the soil for long periods. The other viruses in this group, and which lose their infectivity more rapidly, are believed by Bawden to have some active phase of their existence in the soil.

The case of lettuce big-vein is somewhat different since, in 1958, Grogan, *et al.* (*11*), presented evidence that the big-vein disease of lettuce was intimately associated with infection of roots by the fungus *Olpidium brassicae* (Wor.) Dang. These investigators believed that there is a possibility that lettuce big-vein may be caused by a virus that is transmitted by *Olpidium*, but favored the theory that the symptoms result from a substance produced by the fungus and which is translocated to the leaves. The viruses that cause wheat mosaics were believed by McKinney (*16*) to be capable of overseasoning in the soil. In 1959 Walkinshaw and Larson (*18*) demonstrated that the corky ringspot disease of potatoes was soil-borne.

As to the possibility that nematodes might be involved in the spread of chlorotic streak in sugarcane, the writer's belief is that this could occur since nematodes have already been shown to be capable of acting as vectors of other plant viruses. For example, in 1958 Hewitt, Raski, and Gobeen

(*15*) presented evidence that the dagger nematode, *Xiphinema index*, was the vector of the grapevine fanleaf virus. This seems to be the first report in the literature implicating a nematode as vector of a plant virus. Recently Harrison and Cadman (*12*) in England demonstrated that a species of *Xiphinema* related to or identical with *Xiphinema diversicaudatum* was responsible for the spread of Arabis mosaic virus. It seems likely that many other plant viruses will also be shown to be transmitted by nematodes. Work is being carried on in Puerto Rico to obtain further information on the spread of the causal agent of the chlorotic-streak disease through the soil, and further studies are in progress on the possible role played by nematodes with respect to this disease.

From studies herein reported it is known for the first time that Napier grass is definitely a host for the causal agent of the chlorotic-streak disease. The ecological conditions which favor the expression of symptoms and the spread of the disease in this host seem to be the same as for sugarcane. If the soils should become contaminated for any length of time with the agent that causes chlorotic streak then the disease will probably become more dangerous than it is at present.

SUMMARY

Transmission of the causal agent of the chlorotic-streak disease of sugarcane was effected when diseased and healthy plants were grown together in white quartz sand with ample moisture. Several healthy plants developed symptoms of chlorotic streak when they were grown in soil obtained from around and beneath severely affected plants from the field.

It was found that the causal agent of the chlorotic-streak disease of Napier grass is the same entity that causes the chlorotic-streak disease of sugarcane. Healthy sugarcane plants developed typical symptoms of chlorotic streak when grown together with affected Napier grass plants in nutrient solution.

Unsuccessful attempts were made to infect healthy sugarcane plants by mechanical inoculation of their roots with extracts obtained from roots of affected plants.

RESUMEN

El agente etiológico de la raya clorótica de la caña de azúcar se trasmitió de plantas enfermas a plantas sanas cuando éstas crecieron juntas, bajo condiciones controladas, en arena de cuarzo. Durante el curso del experimento esta arena se mantuvo siempre saturada de agua. También se infectaron plantas sanas que fueron sembradas en tierra que se obtuvo del área inmediata a las raíces de plantas enfermas que crecían en el campo.

Todas las indicaciones son de que el agente etiológico de la raya clorótica

de la yerba Napier es el mismo que causa la raya clorótica en la caña de azúcar.

No se logró infectar plantas sanas de caña de azúcar cuando se frotaron sus raíces con extractos obtenidos de las raíces de las plantas afectadas.

LITERATURE CITED

1. Abbott, E. V., personal communication.
2. Abbott, E. V., and Ingram, J. W., Transmission of chlorotic streak of sugarcane by the leafhopper *Draeculacephala portola*, *Phytopath.* **32** 99–100, 1942.
3. Abbott, E. V., and Sass, J. E., Pathological Histology of sugarcane affected with chlorotic streak, *J. Agr. Res.* **70**(6) 201–7, 1945.
4. Antoine, R., Cane diseases: I, Chlorotic Streak, An. Rept. Mauritius Sugar Ind. Res. Inst. 53–57, 1957.
5. Bawden, F. C., Plant Viruses and Virus Diseases, Chron. Botanica Co., Waltham, Mass. 3d. ed., 335 pp., 1950.
6. Bird, J., Cibes, H., and Tió, M. A., Transmission of the Causal Agent of the Chlorotic-Streak Disease of Sugarcane through the Roots of Plants Grown in Nutrient Solution, Agr. Exp. Sta., Univ. P.R., Tech. Paper 27, 1958.
7. Boneta, E., personal communication.
8. Bruehl, G. W., Chlorotic-streak disease of *Pennisetum purpureum*, USDA *Plant Dis. Reptr.* **37** 34–5, 1953.
9. Bruehl, G. W., and Boneta, E., A chlorotic-streak disease of Merker grass (*Pennisetum purpureum*), *J. Agr. Univ. P.R.* **39**(4) 190–7, 1955.
10. Carpenter, C. W., A Chytrid in relation to chlorotic-streak disease of sugarcane, Hawaiian Planters Rec. **44** 19–33, 1940.
11. Grogan, R. G., Zink, F. W., Hewitt, Wm. B., and Kimble, K. A., The association of *Olpidium* with the big-vein disease of lettuce, *Phytopath.* **48** 292–7, 1958.
12. Harrison, B. D., and Cadman, C. H., Role of a dagger nematode (*Xiphinema* sp.) in outbreaks of plant diseases caused by Arabis mosaic virus, *Nature* **184**(4699) 1624–6, 1959.
13. Hawaiian Sugar Planters' Association, Rept. of Exp. Sta. Committee, 1949.
14. Hawaiian Sugar Planters' Association, Rept. of Exp. Sta. Committee, 1957.
15. Hewitt, Wm. B., Raski, D. J., and Goheen, A. C., Nematode vector of soil-borne fanleaf virus of grapevines, *Phytopath.* **48** 587–94, 1958.
16. McKinney, H. H., Soil-borne wheat mosaic viruses in the Great Plains, USDA *Plant Dis. Reptr.* **37** 24–6, 1953.
17. Sturgess, O. W., Transmission of chlorotic streak, *Cane Growers Quart. Bul.* **23**(2) 42–4, 1959.
18. Walkinshaw, C. H., and Larson, R. H., Corky Ringspot of Potato, a Soil-Borne Virus Disease, Univ. of Wis. Res. Bul. 217, 1950.

Coefficient of Friction, Angle of Repose, Specific Gravity, and Bulk Density of Coffee Fruits and Coffee Beans[1]

Adolfo Eschenwald and Carl W. Hall[2]

INTRODUCTION

Coffee is a very important crop in the world market. On its production, processing and marketing depends, to a great extent, the economy of several countries in North America, South America, Africa, and Asia. Over 90 percent of American families serve coffee and more American families use coffee regularly than any other table item except sugar and salt. A great amount of research work has been done on varieties and cultural practices, but very little basic information is available on handling and processing.

Coffee requires considerable farm handling during processing, from the time the ripe fruits are picked until the product is marketed. Basic information on the physical properties of the coffee fruit and coffee beans is an essential engineering tool for the design of processing systems and structures (fig. 1). The study reported herein was carried out to obtain information on some of the physical properties of coffee.

The specific objectives of this study were:

1. To determine the coefficient of friction between the coffee fruits, beans, and pulp at different stages of the process of elaboration and the important materials of construction.

2. To determine the average specific gravity and bulk density of coffee fruits and pulp, and their applicability to sorting and conveying.

REVIEW OF LITERATURE

The coefficient of friction of a product against a certain surface is expressed as the tangent of the minimum angle at which the product slides over the surface. The angle of repose is the minimum angle at which the product slides over itself. Wifred (*8*)[3] reported some results of studies on angle of repose and coefficient of friction for wheat, barley, oats, corn, beans, peas, and flaxseed on rough boards, iron, and concrete. Jamieson (*2*) de-

[1] Based on "Some basic properties of the coffee fruit and coffee beans," thesis of Adolfo Eschenwald, for M.S. degree, Department of Agricultural Engineering, Michigan State University, East Lansing, Mich., 1959.

[2] Head, Department of Agricultural Engineering, Puerto Rico Agricultural Experiment Station, Mayagüez, P.R., (formerly a graduate student at Michigan State University) and Professor, Agricultural Engineering, Michigan State University.

[3] Italic numbers in parentheses refer to Literature Cited, p. 25.

termined the coefficient of friction between wheat and various materials of construction. Ketchum (*4*) reported data compiled from experiments conducted by V. Pleisener on the coefficient of friction for wheat and rye and bin-wall materials. Values reported for similar materials and grain are different from the values reported by Jamieson (*2*) probably due to variety and moisture content. Kramer (*5*) determined the angle of repose and coefficient of friction for rice and several construction materials. The moisture content of the product was considered. Hintz and Schinke (*1*) determined the coefficient of sliding friction for chopped corn and alfalfa on steel at sliding velocities from 0 to 6,000 f.p.m. Richter (*7*) conducted laboratory tests to determine the friction coefficient for chopped hay, straw, and silage on galvanized steel. The information is used as a basis for the

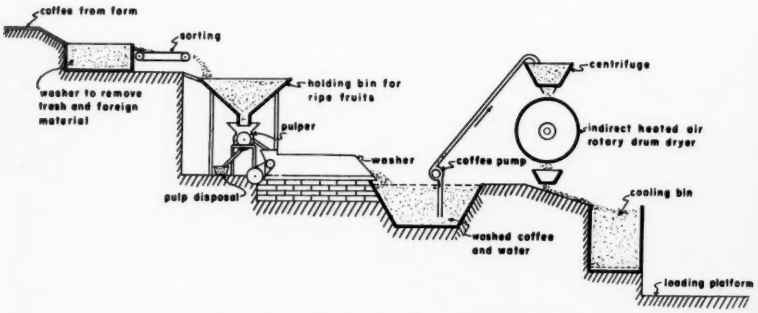


FIG. 1.—A coffee-processing flow-chart.

design of conveyors, bins, and gravity-flow systems. Kinch (*3*) reported data on the coefficient of sliding friction for passion-fruit slices while explaining the design of a passion-fruit centrifuge.

Measurements of the specific gravity and bulk density of a crop are also of value. The specific gravity of a product is expressed as the ratio of mass of the body to the mass of an equal volume of water at 4° C. Work on specific gravity and air space in grain and seed was performed by the use of the specific-gravity-bottle principle. Mercury was used as a fluid. Pflug, *et al.*, (*6*) designed, constructed, and operated, at Michigan State University, a specific-gravity separator for potatoes. Sodium chloride brine was used as the separating medium.

EXPERIMENTAL PROCEDURE

The coffee used in this study was *Coffea arabica* "forma nativa," from Puerto Rico. A conventional tilting table, shown in figure 2, was used to determine the angle at which the product slid over the surface. A card-

board, bottomless frame was used to hold the sample, so that the product did not roll or tip and in such a way that only the product came in contact with the surface being tested. The table was slowly tilted until the product slid on the surface. The angle was measured with a protractor, the tangent being considered as the coefficient of friction. All tests where the product tilted or rolled were discarded. The data in table 1 are the average of four tests where the product slid over the surface without rolling and the holding frame did not come in contact with the surface.

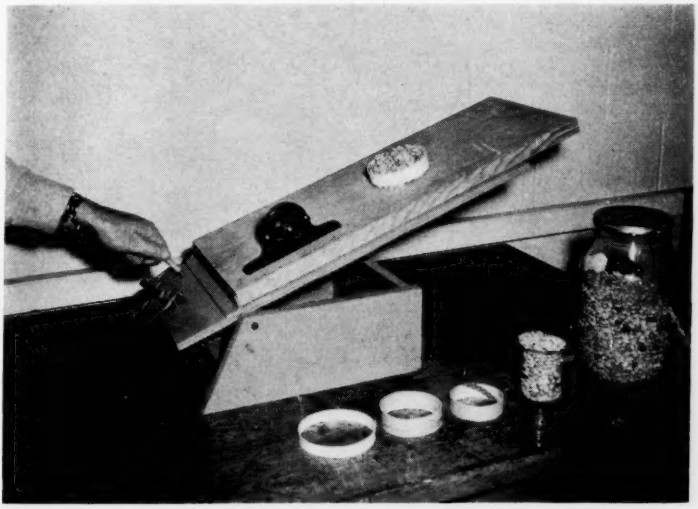


FIG. 2.—Tilting table used for determinations of the coefficient of friction.

The angle of repose of the product, or the coefficient of friction of the fruit over itself, was determined as follows: A box 12 inches wide, 12 inches long, and 6 inches high with a round orifice, and 2 inches in diameter in the center of the bottom, was prepared. A sliding gate on the underside of the orifice permitted the opening to be closed or opened without disturbing the box contents. The box was leveled on top of two blocks providing a free flow. The product was placed in the box and the gate opened, it flowed out undisturbed, until its normal angle of repose was reached. This angle was measured and its tangent was considered the coefficient of friction of the product over itself. Data obtained are also included in table 1.

The specific gravity was determined from a random sample of 100 green and 100 ripe fruits. A Boerner sampler was used to assure the selection of representative fruits. Distilled water at known temperatures was used

TABLE 1.—*Coefficient of friction of coffee fruits and coffee beans measured on various materials of construction*

Treatment	Ripe fruits		Green fruits		Just pulped unwashed beans	Fresh pulp	Just washed wet beans	Dry beans (12-percent moisture dry basis)
	Dry surface	Wet surface	Dry surface	Wet surface				
Concrete (wood-floated)	0.64	0.59	0.64	0.62	.94	.70	1.03	0.55
Concrete (as taken from forms)	.68	.55	.59	.59	.93	.62	.98	.51
Rough wood (with grain)	.61	.75	.77	.85				
Rough wood (across grain)	.68	.74	.59	.66				
Planed wood (with grain)	.61	.70	.51	.67	.90	.75	1.07	.42
Planed Wood (across grain)	.61	.66	.59	.67	.93	.81	1.15	.49
Plywood (with grain)	.59	.69	.50	.60				.47
Plywood (across grain)	.64	.71	.55		.62			.53
Galvanized iron	.57	.47	.50	.47	.54	.60	.87	.40
Aluminum	.58	.52	.54	.47	.49	.58	.78	.40
Stainless steel	.64	.55	.49	.45			.65	.34
Steel	.59	.49	.59	.58	.65	.73	.90	.53
Steel-perforated 1/16 diam. 8/sq. in.							.90	
Steel-perforated 1/8 diam. 16/sq. in.							.90	
Steel-perforated 5/32 diam. 16/sq. in.							.90	
Steel-perforated 3/16 diam. 13/sq. in.							.75	
Window screen 14 x 18 mesh	.78	.79	.65	.65			1.11	
Green fruit				1.33				
Ripe fruit		1.15						

for the determinations by the conventional Archimides' principle. An analytical balance was used for weighing to an accuracy of 4 decimal places. The fresh coffee fruits do not absorb water because of their almost impervious covering and the fact that the intracellular space is saturated, so there is

no water-vapor pressure gradient at uniform temperature and under saturation conditions. The fruits that floated were discarded, since upon opening they exhibited aborted embryos. The bulk densities for green and ripe fruits and the pulp were obtained by weighing a certain quantity of the product and then measuring the volume this same amount occupied when in the normal state.

RESULTS AND DISCUSSION

The results obtained for the coefficient of friction between the product and different materials of construction are presented in table 1. Higher

TABLE 2.—*Specific gravity and density of green and ripe coffee fruits*

Condition of fruits	Specific gravity[1]	Temperature of water, °F.[1]	Weight density in—[1]	
			Gm./cu. cm.	*Lb./cu. ft.*
Green	1.0722*	79° F.	1.0687	66.76
Ripe	1.0454**	80° F.	1.0415	65.07

[1] Average of 100 determinations. * Ranges from 1.0063 to 1.1163; ** ranges from 1.0072 to 1.0884.

TABLE 3.—*Bulk density of coffee fruits and coffee pulp*

Fruits or pulp	Number of fruits[1] per—		Weight density as—[1]		Void space (percent)
	Cubic centimeter	Cubic foot	Gm./cu. cm.	Lb./cu. ft.	
Green	0.546	15,460	0.601	37.54	44
Ripe	.361	10,222	.596	37.24	43
Pulp[2]			.248	15.48	

[1] Average of 20 determinations.
[2] Freshly removed pulp.

values were obtained for the wet product on wood. These results are to be expected because the grain of the wood becomes rougher upon soaking with water. Coefficients of friction for perforated material are useful for studying the movement of material from which excess water is removed after washing and before drying.

No significant difference was found in the average specific gravity and density of green and ripe fruits. (See tables 2 and 3.) The specific gravity for the green fruits varied from 1.0063 to 1.1163 and for the ripe fruits from 1.0072 to 1.0884. Contrary to expectations the green fruits showed a higher average specific gravity than the ripe. The higher average value in specific gravity and density of the green fruit seems to have been caused by some physicochemical changes that occur on ripening. The values obtained for

specific gravity, bulk density, and void space for coffee may be compared with the values obtained for wheat, oats, corn, buckwheat, and millet by Zink (*9*). Results obtained are summarized in tables 2 and 3.

SUMMARY

The coefficients of friction between coffee fruit, coffee beans, and different construction materials were determined by the tilting-table method. Determinations were performed for dry-surface and wet-surface fruit, pulp, pulped unwashed-wet, and pulped washed-dry beans. The pulped, washed, wet beans showed the highest coefficient of friction when compared with fruits, pulp, pulped-unwashed or pulped-washed dry beans for all materials of construction. Values obtained ranged from 0.65 for stainless steel to 1.15 for planed wood (across grain). The dry beans, 12-percent moisture content, dry basis, showed the lowest coefficient of friction when compared with fruits, pulp, pulped-unwashed or pulped-washed wet beans. The values obtained varied from 0.34 for stainless steel to 0.55 for concrete. These values are similar to those obtained for rough rice by Kramer (*5*) on the same materials.

The specific gravity for green fruit varied from 1.0063 to 1.1163 and for the ripe fruit from 1.0072 to 1.0884. The values obtained for specific gravity, bulk density, and void space for coffee are similar to the values published by Zink (*9*) for wheat, oats, buckwheat, and millet.

RESUMEN

El coeficiente de rozamiento entre el café en fruta, el café despulpado y distintos materiales de construcción se determinó mediante el método convencional del plano inclinado. Se hicieron determinaciones entre café en fruta, café despulpado húmedo y café despulpado seco sin pilar con distintos materiales corrientes de construcción, a base de superficies secas y húmedas. El café recién despulpado y mojado mostró el mayor coeficiente de rozamiento. Los valores obtenidos fluctuaron desde 0.65 para acero inoxidable hasta 1.15 para madera acepillada. El café pergamino con 12 por ciento de humedad (base seca) demostró el más bajo coeficiente de rozamiento y los valores obtenidos variaron desde 0.34 para acero inoxidable hasta 0.55 para hormigón. Estos valores se asemejan mucho a los valores obtenidos por Kramer (5) para el arroz en cáscara.

El peso específico obtenido para la fruta de café verde varió desde 1.0063 hasta 1.1163 y para la fruta madura desde 1.0072 hasta 1.0884.

Los valores obtenidos para peso específico, densidad de volumen y espacio libre entre el producto, es similar al publicado por Zink (9) para trigo, avena y millo.

LITERATURE CITED

1. Hintz, O. E. and Schinke, R., Coefficient of Sliding Friction for Corn and Alfalfa on Steel, Advanced Engineering Department, International Harvester Co., Report 3-A1866-52, R.I. Chicago, Ill., 1952.
2. Jamieson, J. S., Grain pressures in deep bins, *Can. Soc. Civ. Engs., Trans.* 1093-17, 554-607, 1905.
3. Kinch, D. M., Development of the passion fruit centrifuge, paper presented at the annual meeting of the A.S.A.E. at Santa Barbara, Calif., June, 1958.
4. Ketchum, M. S. Design of Walls, Bins, and Grain Elevators, pp. 346–50, New York, N. Y., 1911.
5. Kramer, H. A., Factors influencing the design of bulk storage bins for rough rice, *Agr. Eng.* **25** 463–6, 1944.
6. Pflug, I. J., Brandt, M. W., and Isleib, D. R., Specific gravity potato separator, *Mich. Agri. Exp. Sta. Quart. Bul.* **38** 29–34, 1955.
7. Richter, D. W., Friction coefficients of some agricultural materials, *Agr. Eng.* **35** 411–3, 1954.
8. Wifred, A., The pressure of grain, Inst. Civ. Engs., *Minutes of Proceedings*, **121** 347–58, 1898.
9. Zink, F. J., Specific gravity and air space of grains and seeds, *Agr. Eng.* **16** 439–40, 1935.

Snap Bean-Variety Trials at the Lajas Substation

Oscar D. Ramínez and José A. Quiñones[1]

INTRODUCTION

Snap beans are among the most important vegetables grown in home gardens and in market-garden areas. A knowledge of yielding ability, days to maturity, insect and disease resistance, and adaptability to the area is needed in order to make variety recommendations. Variety trials of snap beans were conducted at the Lajas Substation to obtain some of this information.

POLE BEANS

MATERIALS AND METHODS

On September 16, 1959, five pole-bean varieties were tested at the Lajas Substation in a 5-x-5-foot Latin-square design. Each plot consisted of two rows 4 feet apart and 20 feet long. In each row 10 hills were planted 2 feet apart with two plants per hill. A 9-10-5 fertilizer at the rate of 800 pounds per acre (*1*)[2] was applied to the planting.

The five varieties (*2*) tested were Florigreen, Blue Lake 92, Blue Lake 228, Blue Lake 231, and Kentucky 191. All varieties are white-seeded and commercially grown in the United States.

Beans were harvested at the best edible and marketable stage. Seventeen pickings at intervals of a few days were made to complete the harvesting of the crop.

EXPERIMENTAL RESULTS

The results obtained are presented in tables 1 and 2.

The standard error and least differences required for significance between means in table 2 are shown in the following tabulation:

Item	*5 percent*	*1 percent*
Difference between highest and lowest	6.67	8.64
Difference between highest and 2nd lowest	6.21	8.14
Difference between highest and 3d lowest	5.57	7.45
Difference between highest and 4th lowest	4.55	6.39

The yield of variety Florigreen (*3*) was significantly higher at the 1-percent level than that of Kentucky 191. There were no significant differences

[1] Assistant Plant Breeder and Research Assistant in Plant Breeding, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras and Lajas, P.R.

[2] Italic numbers in parentheses refer to Literature Cited, p. 31.

between the yields of varieties Florigreen, Blue Lake 231, Blue Lake 92, and Blue Lake 228.

Besides being a high yielder, variety Florigreen proved to be highly resistant to bean-mosaic and bean-rust diseases.

TABLE 1.— *Harvesting dates and maturity at harvest of 5 pole-bean varieties planted at the Lajas Substation, September 16, 1959*

Variety	Blooming date	Harvest dates	Days of maturity at first harvest
Florigreen	Oct. 18, 1959	Nov. 3, 6, 9, 12, 16, 18, 20, 23, 25, 27, 30 Dec. 2, 4, 7, 9, 11, 15	49
Blue Lake 231	Oct. 19, 1959	Nov. 3, 6, 9, 12, 16, 18, 20, 23, 25, 27, 30 Dec. 2, 4, 7, 9, 11, 15	49
Blue Lake 92	Oct. 19, 1959	Nov. 3, 6, 9, 12, 16, 18, 20, 23, 25, 27, 30 Dec. 2, 4, 7, 9, 11, 15	49
Blue Lake 228	Oct. 19, 1959	Nov. 6, 9, 12, 16, 18, 20, 23, 25, 27, 30 Dec. 2, 4, 7, 9, 11, 15	52
Kentucky 191	Oct. 19, 1959	Nov. 3, 6, 9, 12, 16, 18, 20, 23, 25, 27, 30 Dec. 2, 4, 7, 9, 11, 15	49

TABLE 2.—*Total and mean yields of 5-pole bean varieties planted at Lajas Substation, September 16, 1959*

Variety	Total yield	Mean yield per plot	Calculated production per acre
	Lb.	*Lb.*	*T./A.*
Florigreen	100.65	20.13	2.74
Blue Lake 231	81.36	16.27	2.21
Blue Lake 92	73.22	14.64	1.98
Blue Lake 228	70.91	14.18	1.92
Kentucky 191	57.29	11.46	1.55

Kentucky 191 was the lowest yielder of the five varieties and proved to be highly susceptible to bean mosaic, making it undesirable for commercial production.

BUSH BEANS

MATERIALS AND METHODS

In 1959 sixteen commercial varieties and six lines of bush snap beans were tried out at the Lajas Substation.

The 16 commercial varieties were planted on January 30, 1959, using a

balanced-lattice design with five replications. Each plot consisted of two rows 3 feet apart (*4*) and 6 feet long. In each row 10 hills were planted 6 inches apart with 1 plant per hill. A 9-10-5 fetilizer at the rate of 1,000 pounds per acre (*5*) was applied to the planting.

The varieties tried were Giant Stringless (*2*), Improved Tendergreen (*6*), Plentiful (*2*), Seminole (*7*), Stringless Black Valentine (*6*), Stringless Greenpod (*6*), Tenderlong (*2*), Tender Pod (*6*), Topcrop (*2*), Gladess (*2*), Contender (*2*), Wade (*2*), Bountiful (*4*), Topmost (*2*), Criolla, and Bonita.

The six lines of snap beans were planted on December 28, 1959, using a 6-x-6-foot Latin square design. Each plot consisted of two rows 3 feet apart and 20 feet long. Each row consisted of 40 plants 6 inches apart, making a total of 80 plants per plot. A 9-10-5 fertilizer at the rate of 800 pounds per acre (*1*) was applied to the planting.

The lines (*8*) tested were B-3365, B-3095-3, B-3076, B-3489, B-3125-x-5-2, and B-2567-1. These lines were received from the Southeastern Vegetable Breeding Laboratory at Charleston, S. C.

In both trials the beans were harvested at the best edible and marketable stage. Four pickings at intervals of a few days were made in order to complete the harvesting of the crop.

EXPERIMENTAL RESULTS

The results obtained from experiment No. 1 using 16 bush varieties are presented in tables 3 and 4.

All varieties, except Bonita were harvested on March 18, 21, 25, and 30, and had 48 days of maturity at that time; Bonita was harvested March 25 and 30 with 55 days of maturity.

The yield of variety Topcrop was significantly higher at the 1-percent level than the yields of varieties Contender, Seminole, Bountiful, Giant Stringless, Stringless Greenpod, Improved Tendergreen, Plentiful, Stringless Black Valentine, Tenderlong, Gladess, Criolla, and Bonita. There were no significant differences between the yields of Topcrop, Wade, Tender Pod, and Topmost. These four varieties, besides being the highest yielders, were also found to be well adapted to the area.

The results obtained from experiment No. 2 using six bush lines are presented in table 5.

The standard error and least differences required for significance between means in table 6 are shown in the following tabulation:

Item	*5 percent*	*1 percent*
Difference between highest and lowest	4.49	5.56
Difference between highest and 2nd lowest	4.28	5.35
Difference between highest and 3d lowest	3.99	5.07
Difference between highest and 4th lowest	3.61	4.67
Difference between highest and 5th lowest	2.97	4.06

TABLE 3.—*Total and mean yields of 16 bush snap bean varieties planted at the Lajas Substation, January 30, 1959*

Variety	Total yield	Mean yield per plot	Calculated production per acre, 1
	Lb.	*Lb.*	*T./A.*
Toperop	26.66	5.33	3.86
Wade	23.05	4.61	3.34
Tender Pod	22.98	4.59	3.33
Topmost	21.83	4.37	3.17
Contender	19.35	3.87	2.80
Seminole	18.87	3.77	2.73
Bountiful	18.45	3.69	2.67
Giant Stringless	18.36	3.67	2.66
Stringless Greenpod	18.27	3.65	2.65
Improved Tendergreen	18.18	3.64	2.64
Plentiful	16.62	3.32	2.41
Stringless Black Valentine	15.29	3.06	2.22
Tenderlong	14.85	3.97	2.15
Gladess	14.26	2.85	2.06
Criolla	13.82	2.76	2.00
Bonita	13.48	2.70	1.96

TABLE 4.—*A summary of treatments used and results obtained in the bush snap bean-variety trial planted at the Lajas Substation, January 30, 1959*

Variety and No.	Treatment mean	Better at 1-percent than treatment, Nos.	Better at 5-percent than treatment, Nos.
Toperop, 9	5.33	11, 4, 13, 1, 6, 2, 3, 5, 7, 10, 15, 16	11, 4, 13, 1, 6, 2, 3, 5, 7, 10, 15, 16
Wade, 12	4.61	5, 7, 10, 15, 16	3, 5, 7, 10, 15, 16
Tender Pod, 8	4.59	5, 7, 10, 15, 16	3, 5, 7, 10, 15, 16
Topmost, 14	4.37	5, 7, 10, 15, 16	5, 7, 10, 15, 16
Contender, 11	3.87	.....	.....
Seminole, 4	3.77	.....	.....
Bountiful, 13	3.69	.....	.....
Giant Stringless, 1	3.67	.....	.....
Stringless Greenpod, 6	3.65	.....	.....
Improved Tendergreen, 2	3.64	.....	.....
Plentiful, 3	3.32	.....	.....
Stringless Black Valentine, 5	3.06	.....	.....
Tenderlong, 7	2.97	.....	.....
Gladess, 10	2.85	.....	.....
Criolla, 15	2.76	.....	.....
Bonita, 16	2.70	.....	.....

The blooming date for 4 of the bush lines mentioned under "Materials and Methods" above was January 27, 1960, but for B-3365 and B-3125-x-5-2 it was January 26, 1960. The harvest dates for all lines were February 10, 15, 19, and 23, and their maturity at harvest was 45 days.

No significant differences were found between the yields of the six lines of snap beans. All six lines look very promising for commercial production, taking in consideration their yielding ability, disease resistance, pod appearance and quality.

SUMMARY

Snap bean-variety trials were conducted at the Lajas Substation. Three different experiments were planted, one of pole beans and two others of bush beans.

TABLE 5.—*Total and mean yields of 6 lines of snap beans planted at the Lajas Substation, December 28, 1959*

Lines	Total yield	Mean yield per plot	Calculated production per acre
	Lb.	*Lb.*	*T./A.*
B-3125-x-5-2	95.21	15.87	2.88
B-2567-1	92.22	15.37	2.78
B-3095-3	90.89	15.15	2.74
B-3365	90.01	15.00	2.72
B-3489	77.64	12.92	2.34
B-3076	69.55	11.59	2.10

The five varieties of pole beans tested were Florigreen, Kentucky 191, Blue Lake 92, Blue Lake 228, and Blue Lake 231.

Of the five pole varieties tested, variety Florigreen was the highest yielder. It also showed to be highly resistant to bean-mosaic and bean-rust diseases.

Sixteen bush snap beans were also tested. They were Topcrop, Wade, Tender Pod, Topmost, Contender, Seminole, Bountiful, Giant Stringless, Stringless Greenpod, Improved Tendergreen, Plentiful, Tenderlong, Stringless Black Valentine, Gladess, Criolla, and Bonita. According to their yield and adaptability to the area, only four varieties look promising. They are Topcrop, Wade, Tender Pod, and Topmost.

Also six lines of bush snap beans received from the Southeastern Vegetable Breeding Laboratory were tested. No significant differences were found between their yields. All six lines B-3365, B-3095-3, B-3076, B-3489, B-3125-x-5-2, and B-2567-1 look very promising, taking in consideration their yielding ability, disease resistance, pod appearance, and quality.

RESUMEN

En la Subestación de Lajas se llevaron a cabo pruebas con variedades de habichuelas tiernas. Se sembraron tres experimentos, uno de habichuelas trepadoras y dos de arbustivas.

Las cinco variedades trepadoras que se probaron fueron, *Florigreen, Kentucky 191, Blue Lake 92, Blue Lake 228* y *Blue Lake 231.* De estas cinco variedades, la *Florigreen* fue la de más alta producción. También demostró ser altamente resistente a las enfermedades del mosaico y la roya de la habichuela.

Las 16 variedades de habichuelas arbustivas que se probaron fueron las siguientes: *Topcrop, Wade, Tender Pod, Topmost, Contender, Seminole, Bountiful, Giant Stringless, Stringless Greenpod, Improved Tendergreen, Plentiful, Tenderlong, Stringless Black Valentine, Gladess,* Criolla y Bonita. De estas variedades y de acuerdo con su producción y adaptabilidad a la zona, las siguientes resultaron superiores: *Topcrop, Wade, Tender Pod* y *Topmost.*

Se probaron también seis líneas de habichuelas arbustivas enviadas por el Laboratorio de Desarrollo de Hortalizas del Sureste de los Estados Unidos. No se encontró diferencia significativa alguna entre las producciones de estas líneas.

Las variedades B-3365, B-3095-3, B-3076, B-3489, B-3125-x-5-2 y B-2567-1 demostraron ser muy prometedoras por su capacidad productiva, resistencia a las enfermedades y por la apariencia y calidad de la vaina.

LITERATURE CITED

1. Compendio de Recomendaciones para la Producción de Cosechas, Pub. Misc. 1. Est. Exp. Agr. Univ. P.R., (rev.) 1954.
2. Asgrow Export Corp., A Descriptive Catalog of Vegetables, No. 19.
3. Walter, J. M., and Lorz, A. P., Florigreen, A Disease-Resistant Pole Bean, Circ. S-92, Fla. Agr. Exp. Sta., 1956.
4. Zaumeyer, W. J., Snap beans for Marketing, Canning, and Freezing, Farmer's Bul. 1915, U.S.D.A. (rev.) Sept. 1954.
5. González-Ríos, P., y Riollano, A., El Mejoramiento de la Habichuela Blanca del País (*Phaseolus vulgaris*) por Medio de la Selección, Bol. 94, Est. Exp. Agr., Río Piedras, P.R.
6. W. Atlee Burpee Co., Burpee Seeds, 1959.
7. Wolf, E. A. and Hills, W. A., Seminole—A New Disease-Resistant, Green, Round-Podded Bush Bean, Circ. S-73, Fla. Agr. Exp. Sta., 1954.
8. Nineteenth and Twentieth Annual Report of Vegetable Breeding in the Southeastern United States, Hawaii, and Puerto Rico, Southeastern Vegetable Breeding Laboratory, Agricultural Research Service, USDA, Charleston, S.C., 1958–59.

Beef Production and Carrying Capacity of Heavily Fertilized, Irrigated Guinea, Napier, and Pangola Grass Pastures on the Semiarid South Coast of Puerto Rico[1]

Rubén Caro-Costas, José Vicente-Chandler, and Calvin Burleigh[2]

INTRODUCTION

Little, Vicente-Chandler, and Abruña (*2*)[3] found that Napier and Guinea grass growing under close to optimum conditions of heavy fertilization and irrigation yielded about 26 and 21 tons, respectively, of dry forage per acre yearly with about a 10-percent protein content, when harvested by cutting every 60 days. Yields and protein content of the grasses increased with nitrogen rates up to 800 pounds per acre yearly.

The purpose of the present study was to determine the productivity in terms of carrying capacity and actual gains in weight, of Guinea grass (*Panicum maximum*), Napier grass (*Pennisetum purpureum*), and Pangola grass (*Digitaria decumbens*) pastures under similar conditions of heavy fertilization and irrigation.

MATERIALS AND METHODS

The experiment was carried out near Santa Isabel, on the semiarid south coast of Puerto Rico, with a mean annual temperature of about 75° F., and a seasonal variation of less than 10° F. Annual rainfall is approximately 35 inches with a marked dry season from about December through April.

The soil is a deep, almost level, well-drained San Antón sandy clay loam, which had been in sugarcane for many decades. The surface 6 inches had about 2.5 percent of organic matter and 0.15 percent of nitrogen, a pH of 7.5, 36 m.e. of exchange capacity per 100 gm. of soil, a volume-weight of 1.3, and about 10 percent of the pores drained at a tension of $\frac{1}{3}$ atmosphere.

The field was divided into 12 one-acre pastures and the three grasses assigned to them in a randomized block design with four replications. Each enclosure was provided with shade, water, and salt blocks (fig. 1).

[1] This report covers work carried out cooperatively between Luce and Co., the Soil and Water Conservation Research Division, Agricultural Research Service, USDA and the University of Puerto Rico Agricultural Experiment Station, Río Piedras, P.R.

[2] Agronomist, University of Puerto Rico and USDA, Soil Scientist, USDA, and former Director of Research, Luce & Co., respectively.

[3] Italic numbers in parentheses refer to Literature Cited, p. 36.

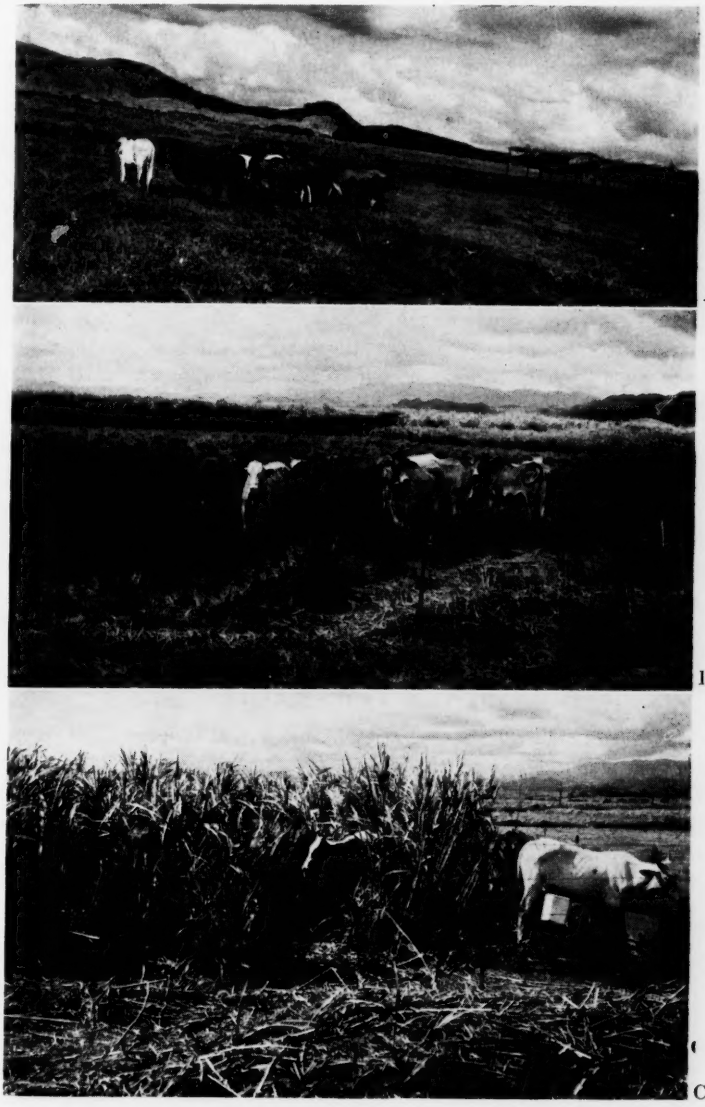


FIG. 1.—Cattle grazing heavily fertilized, irrigated pastures of: A, Pangola grass; B, Guinea grass; C, Napier grass. The latter 2 grasses yielded about 1,300 pounds gain-in-weight per acre yearly with a carrying capacity of 2.2 standard beef-cows (about 3 steers) per acre and daily gains per head of about 1¼ pound.

Fertilizer equivalent to about 3,000 pounds of a 14-4-10 fertilizer was applied per acre yearly to all pastures in approximately 10 equal applications. Irrigation was applied by sprinklers whenever needed to provide the pastures with about 1½ inches of water weekly. However, the pastures occasionally suffered from drouth due to failure of the irrigation system. All pastures were mowed twice yearly.

Young steers of Brahma, Brahma-Angus, and Brahma-native crosses initially weighing about 400 pounds and of similar age and condition were used. The first group was grazed on the pastures for 9 months and another similar group during the following 9 months. The steers were divided into three groups, one for each grass, and treated for parasites. A minimum of 2½ steers was kept per acre at all times. Additional animals were added occasionally to consume the excess forage produced during seasons of flush growth, using the well-known "take-and-put" method. The four pastures of each grass were grazed in rotation with about 8 days of grazing followed by a 24-day rest period. The steers received no feed other than that obtained from the pastures.

The steers were weighed every time they were moved from one pasture to another and a record was kept of grazing days, animal weights, and gains in weight for each pasture. The total digestible nutrients (T.D.N.) produced by each pasture were calculated following the recommendations of the Pasture Research Committee (*3*)[4]. Carrying capacities were calculated from these data using the accepted value of 12 pounds T.D.N. daily for a standard beef cow.

RESULTS AND DISCUSSION

The data in table 1 show that the Guinea and Napier grass pastures were approximately equal in productivity, yielding about 1,300 pounds of gain-in-weight and 9,500 pounds of T.D.N. per acre yearly, with a carrying capacity of 2.2 standard beef cows, or about 3 steers per acre. Daily gains per head averaged about 1¼ pounds which is considered fairly good for steers feeding on grass alone.

The performance of Pangola grass tended to be inferior in all these terms, although the differences fall short of statistical significance. Soon after planting, the Pangola grass was killed out by a severe attack of the yellow sugarcane aphid (*Sipha flava*) and had to be replanted. However, it was not seriously attacked by this pest during the period of experimentation.

On expensive land such as this, where complete mechanization is possible, it may be best to harvest grasses by cutting in order to attain maxi-

[4] Pounds average weight × 0.007925 × days of grazing = pounds T.D.N. for maintenance. Pounds gain in weight × 3.53 = pounds T.D.N. for gains in weight.

mum productivity. Assuming that digestibility of the forage under grazing management was about 50 percent, as estimated by Caro and Vicente-Chandler (*1*), the Guinea and Napier grass pastures in this experiment yielded about 20,000 pounds of dry forage per acre yearly. This is only about half as much as they yielded under cutting management in the adjacent experiment by Little, Vicente-Chandler, and Abruña (*2*).

SUMMARY

The productivity of Guinea grass, Napier grass, and Pangola grass pastures under close to optimum conditions of heavy fertilization, irrigation, and intensive grazing management on almost level land on the semiarid south coast of Puerto Rico was determined in terms of carrying capacity and actual gains in weight over a period of 1½ years.

Guinea and Napier grass pastures produced about 1,300 pounds of gain-in-weight and 9,500 pounds of total digestible nutrients per acre yearly, with a carrying capacity of 2.2 standard beef cows, or about 3 steers per acre. Daily gains per young steer averaged about 1¼ pounds. The Pangola grass pastures averaged 1,063 pounds of gain-in-weight and 7,934 pounds of total digestible nutrients per acre yearly.

TABLE 1.—*The productivity of heavily fertilized, irrigated Guinea, Napier, and Pangola grass pastures on level San Antón sandy clay loam on the semiarid south coast of Puerto Rico, grazed by young steers*

Grass	Gains in weight per acre yearly	T.D.N. consumed by cattle[1] per acre yearly	Standard beef cow-days of grazing per acre yearly[2]	Carrying capacity for standard beef cows per acre	Actual steer-days of grazing per acre yearly	Average daily gains per head
	Pounds	*Pounds*	*Number*	*Number*	*Number*	*Pounds*
Guinea	1,292	9,756	813	2.23	1,080	1.23
Napier	1,327	9,301	775	2.12	1,014	1.30
Pangola	1,063	7,934	661	1.81	953	1.12

[1] Calculated from body-weights, days of grazing, and gains in weight, following recommendations of the Pasture Research Committee (*3*).

[2] 1 beef-cow requires 12 pounds of T.D.N. daily.

RESUMEN

Se determinó la productividad, en términos de aumento en peso y capacidad de pastoreo, de los pastos de yerba Guinea, Napier y Pangola cultivados bajo condiciones casi óptimas de alta fertilidad, riego y pastoreo intensivo en terreno llano de la zona semiárida de Puerto Rico durante un año y medio.

Los pastos de yerba Guinea y Napier produjeron anualmente alrededor

de 1,300 libras de aumento en peso y 9,500 libras de nutrientes digeribles por cuerda. Su capacidad de pastoreo fue de 2.2 vacas tipo carne, ó aproximadamente 3 novillos por cuerda. Los novillos aumentaron alrededor de una libra y cuarta por día. Los pastos de yerba Pangola produjeron, en promedio, 1,063 libras de aumento en peso y 7,934 libras de nutrientes digeribles por cuerda por año.

LITERATURE CITED

1. Caro-Costas, R., and Vicente-Chandler, J., Effect of fertilization on carrying capacity and beef produced by Napier grass pastures, in press, *Agro. J.*
2. Little, S., Vicente-Chandler, J., and Abruña, F., Yield and protein content of irrigated Napier grass, Guinea grass, and Pangola grass, as affected by nitrogen fertilization, *Agron. J.* **51**(2) 111-3, 1959.
3. Preliminary Report on Pasture Investigations Technics, Joint Committee of ASA, ADSA, and ASAP, *Agron. J.* **44**(1) 39–50, 1952.

Effects of Nitrogen Fertilization and Frequency of Cutting on the Yield and Composition of Pangola Grass in Puerto Rico[1]

José Vicente-Chandler, Jacinto Figarella, and Servando Silva[2]

INTRODUCTION

Although Pangola is becoming one of the most popular pasture grasses of the Tropics there is little information on the effect of nitrogen fertilization or frequency of cutting on its productivity or composition. Oakes, *et al.* (*3*)[3] in the U.S. Virgin Islands, found that Pangola grass responded in yield, to increasing nitrogen rates up to 300 pounds per acre yearly, while Engibous, *et al.* (*2*), in Florida, found that this grass responded in yield to increasing nitrogen rates up to 320 pounds per acre yearly. Caro-Costas, *et al.* (*1*), in the mountain region of Puerto Rico, found that Pangola grass responded strongly in yield to nitrogen rates up to 400 pounds per acre yearly. They also found that lower yields were obtained when the forage was harvested by simulated grazing every 40 days, than by cutting every 60 days.

This paper presents the results of an experiment carried out to determine the response of Pangola grass to nitrogen fertilization as affected by frequency of cutting.

MATERIALS AND METHODS

The experiment was carried out at Río Piedras, over 2 consecutive years. The mean annual temperature is about 76° F., with seasonal variations of less than 10° F. Rainfall was 103.3 and 60.9 inches during the first and second years, respectively, representing close to record deviations from the long-time average of about 80 inches.

The soil is a Fajardo clay, a deep, red, fairly well-drained soil, on about a 20-percent slope. Initially, the surface 6 inches averaged 3.2 percent of organic matter, 0.17 percent of nitrogen, 12.1 m.e. exchange capacity, and 6.0 m.e. of exchangeable bases per 100 gm. of soil, and had a pH of 4.8.

[1] This work was carried out cooperatively between the U.S. Department of Agriculture and the Agricultural Experiment Station of the University of Puerto Rico, Río Piedras, P.R.

[2] Project Supervisor, Soil Scientist, and Physical Science Technician (General), respectively, Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture.

[3] Italic numbers in parentheses refer to Literature Cited, p. 45.

The treatments used were as follows:

Harvest intervals (days)	*Nitrogen levels (pounds N per acre yearly)*
30	0
	200
45	400
	800
60	1,600

All combinations of these treatments were tested using a split-plot design, with harvest intervals as the main plots and nitrogen levels as the

TABLE 1.—*Inches of rainfall by months during the 2 years of experimentation*

1st year		2nd year	
March 1958	—6.4	March 1959	—2.2
April 1958	—6.5	April 1959	—4.8
May 1958	—20.2	May 1959	—8.4
June 1958	—11.6	June 1959	—2.1
July 1958	—8.3	July 1959	—7.9
August 1958	—7.7	August 1959	—7.0
September 1958	—14.9	September 1959	—5.5
October 1958	—8.1	October 1959	—9.6
November 1958	—6.5	November 1959	—4.6
December 1958	—3.7	December 1959	—5.1
January 1959	—6.8	January 1960	—.6
February 1959	—2.6	Febraury 1960	—3.1
Total	103.3	Total	60.9

subplots. All treatments were replicated three times. Subplots were 10 x 20 feet, surrounded by ditches to prevent fertilizer from washing into adjoining plots.

The upper 6 inches of soil in all plots was limed to a pH of about 6.5 at the start of the experiment. Blanket additions of phosphorus and potassium were made at the rate of 300 pounds of P_2O_5 per acre from 20-percent superphosphate in 1 application, and 600 pounds K_2O from KCl per acre annually in 6 to 12 equal applications, depending on frequency of cutting. The nitrogen was applied as ammonium sulfate in 6 to 12 equal applications yearly, depending on frequency of cutting.

The grass was cut at the prescribed intervals, weighed, and the forage removed from the plots. Samples from each plot at every harvest were analyzed for dry matter and total nitrogen. The crude-protein content was calculated using the factor 6.25 times N. Samples were composited

by plots at the end of the second year and analyzed for calcium, phosphorus, potassium, and lignin.

RESULTS

Table 1 shows the rainfall distribution by months during the 2-year course of the experiment.

TABLE 2.—*The effects of nitrogen fertilization and frequency of cutting on the yield and protein content of Pangola grass and on the efficiency of utilization of the applied nitrogen over a 2-year period*

Nitrogen (pounds)	Yield of green forage per acre yearly	Dry-matter content	Yield of dry matter per acre yearly	Crude-protein content	Crude-protein yield per acre yearly	Recovery of N in forage	Dry matter produced per pound of each increment of N
	Grass cut every 30 days						
	Lb.	*Percent*	*Lb.*	*Percent*	*Lb.*	*Percent*	*Lb.*
0	47,752	20.2	9,650	8.0	773	—	—
200	100,688	16.3	16,414	10.2	1,677	72.3	33.8
400	126,064	15.3	19,260	12.5	2,400	65.1	14.2
800	130,960	15.1	19,785	14.3	2,833	41.2	1.3
1,600	125,599	15.2	19,148	15.0	2,862	20.8	—
	Grass cut every 45 days						
0	40,599	20.8	8,430	6.3	530	—	—
200	101,756	17.4	17,727	8.1	1,427	71.8	46.5
400	136,577	16.8	22,899	9.6	2,201	66.9	25.9
800	140,570	16.8	23,607	11.7	2,764	44.7	1.8
1,600	121,947	16.9	20,585	13.0	2,679	21.5	—
	Grass cut every 60 days						
0	50,440	23.7	11,955	5.5	652	—	—
200	115,957	22.3	25,871	5.8	1,512	68.8	69.6
400	146,889	20.3	29,762	8.0	2,366	68.6	19.5
800	165,958	18.7	30,987	10.8	3,344	53.8	3.1
1,600	153,850	18.6	28,688	12.0	3,429	21.5	—

EFFECT OF LENGTH OF HARVEST INTERVAL

The data in table 2 and figure 1 show that yields increased markedly with length of harvest interval, particularly that from 45 to 60 days. At the 400-pound level of nitrogen, Pangola grass produced 19,260, 22,899, and 29,762 pounds of dry matter per acre yearly when cut at 30-, 45-, and 60-day intervals, respectively. The dry-matter content of the forage also

increased with harvest intervals, averaging 15.3, 16.8, and 20.3 percent for these cutting intervals, respectively.

Figure 2 shows that, at nitrogen rates of 800 pounds or less, yields were similar during both years with a 60-day harvest interval. However with a 45-day harvest interval much lower annual yields were produced during the second, drier year. This may be explained by better root development with the 60-day interval enabling the grass to make full use during dry periods of moisture stored in the soil. Yields were similar over periods of

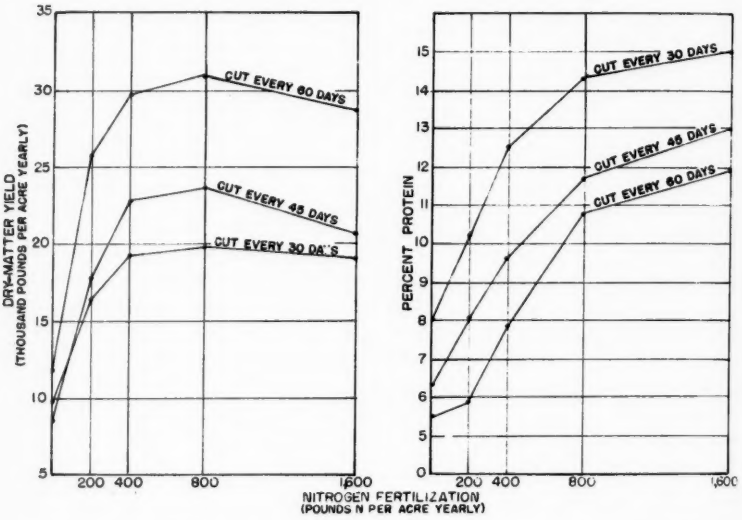


FIG. 1.—Effects of nitrogen fertilization and frequency of cutting on yields and protein content of Pangola grass.

adequate rainfall in both years with the 45-day interval, showing that production was not diminishing with age of the pasture. These results suggest the desirability of using a longer harvest interval during unfavorable seasons and a shorter one during good weather.

The protein content of the forage dropped with each increase in harvest interval averaging, at the 400-pound level of nitrogen, 12.5, 9.6, and 8.0 percent when the grass was cut at 30-, 45-, and 60-day intervals, respectively.

The proportion of applied nitrogen recovered in the forage was not appreciably affected by length of harvest interval.

The data in table 3 show that the phosphorus, potassium, and calcium

contents of Pangola grass tended to decrease slightly while the lignin contents increased slightly with length of harvest interval.

EFFECT OF NITROGEN FERTILIZATION

The data in table 2 and figure 1 show that yields increased rapidly with nitrogen fertilization up to the 400-pound level at all harvest intervals. With a 45-day harvest interval, yields were almost tripled to 22,899

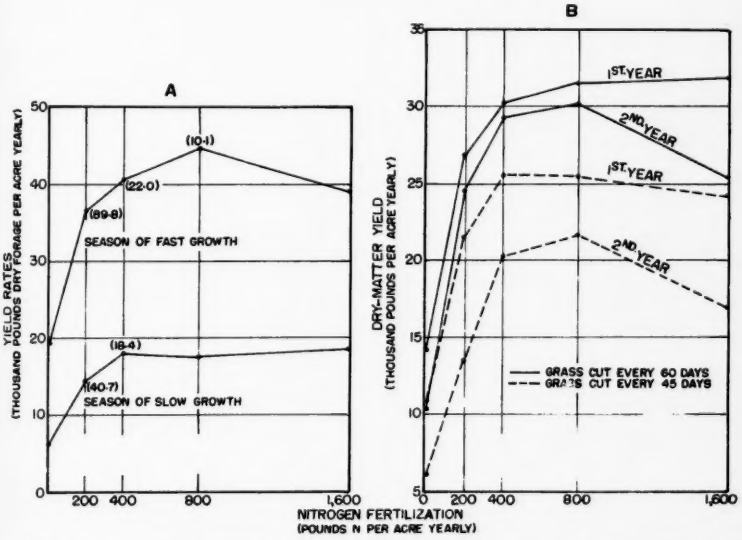


FIG. 2.—Effect of season of the year (A) and years with widely different rainfall (B) on the response of Pangola grass to nitrogen fertilization. In A, numbers in parentheses show pounds of dry forage per pound increment of N; in B, rainfall was 103.3 inches the first year and 60.9 inches the second.

pounds of dry forage per acre yearly by the application of 400 pounds of nitrogen.

Figure 2 shows that despite the sharp difference in yields between seasons of slow (January—March) and of fast growth, Pangola grass responded strongly to the 400-pound nitrogen rate at all times of the year. This figure also shows a strong response to the 400-pound N rate during both years despite the wide difference in rainfall. Yields decreased during the much drier second year when 1,600 pounds of nitrogen were applied due to damage by burning.

The protein content of the forage increased with nitrogen rates up to

the highest level tested averaging, when cut every 45 days, 6.3, 8.1, 9.6, 11.7, and 13.0 percent when fertilized with 0, 200, 400, 800, 1,600 pounds of nitrogen per acre yearly, respectively. The highest protein content of 15.0 percent was attained with a 30-day harvest interval and 1,600 pounds

TABLE 3.—*The effects of nitrogen fertilization and harvest interval on the composition of Pangola grass expressed as percentage on a dry-weight basis*

Nitrogen fertilization (pounds N per acre yearly)	Results at harvest interval indicated			
	30 days	45 days	60 days	Average
		Phosphorus		
400	0.22	0.22	0.18	0.21
800	.19	.18	.14	.17
Average	0.21	0.20	0.16	0.19
		Calcium		
400	0.43	0.36	0.34	0.38
800	.42	.43	.41	.42
Average	0.42	0.39	0.37	0.40
		Potassium		
400	2.6	2.3	1.8	2.2
800	2.3	2.1	1.6	2.0
Average	2.4	2.2	1.7	2.1
		Lignin		
400	8.1	8.8	9.2	8.7
800	8.4	8.5	9.7	8.8
Average	8.2	8.6	9.4	8.7

of nitrogen per acre yearly. The nature of the curve in figure 1 indicates that this is probably close to the maximum protein content attainable with this grass when using a 30-day harvest interval. The assumption is made that the nitrogen was essentially all in the amino form since no more than traces of nitrates were found in the forage.

Protein yields increased rapidly with nitrogen fertilization up to the 800-pound level averaging, with a 45-day harvest interval, 530, 2,201,

and 2,764 pounds per acre yearly at the 0-. 400-, and 800-pound levels of nitrogen, respectively.

The data in table 2 show that from about 65 to 72 percent of the applied nitrogen was recovered in the forage when 400 pounds or less were applied per acre yearly. Percentage recovery decreased with increasing rates above 400 pounds. Pangola grass obtained about 100 pounds of nitrogen per acre yearly from the soil when none was applied as fertilizer.

The efficiency of utilization of fertilizer nitrogen decreased rapidly with increasing rates. With a 45-day harvest interval, 46.5, 25.9, 1.8, and 0 pounds of dry matter were produced per pound of each successive increment of nitrogen.

Figure 2 shows that more dry forage was produced per pound of nitrogen during seasons of flush than during seasons of slow growth. Also, only 41.2 percent of the 400-pound nitrogen application was recovered in the forage during seasons of slow growth, compared to 89.0 percent during seasons of flush growth.

The data in table 3 show that the phosphorus content of the forage decreased slightly with increased nitrogen fertilization, while lignin, potassium, and calcium contents were not apparently affected by fertilization. The data in table 2 show that dry-matter content of the forage decreased slightly with increasing nitrogen rates.

EFFECT OF SEASON OF THE YEAR

It is remarkable that yields were so similar (fig. 2) during both years despite a difference in rainfall of more than 40 inches.

Season of the year, however, had a marked effect on yields. During January and February of both years, Pangola grass receiving 400 pounds of nitrogen per acre yearly and cut every 60 days produced at the rate of only about 17,000 pounds of dry forage per acre yearly, compared to an average rate of about 33,000 pounds for the remainder of the year.

Protein content of the forage also varied considerably with season of the year ranging, with a 45-day harvest interval and 400 pounds of nitrogen, from as low as 6.7 to as high as 14.9 percent. In general, protein content was highest during seasons of slow growth and vice versa.

DISCUSSION

Highest yields were obtained when Pangola grass was cut every 60 days, but the forage was of lower quality as indicated by a higher lignin and lower protein content. It is probably best to harvest Pangola grass about every 45 days, during seasons of fast growth and about every 60 days during the season of slow growth. Pangola grass pastures may be grazed as often as every 25 days during periods of fast growth.

The application of 400 pounds of nitrogen per acre yearly to Pangola grass was apparently warranted with all harvest intervals under the conditions of this experiment.

With a 60-day harvest interval and 400 pounds of nitrogen per acre yearly, Pangola grass produced about 73 tons of green forage, or 29,762 pounds of dry matter with 8.0 percent of protein per acre yearly. This is sufficient to meet the roughage requirements of about four mature cows.

With proper management, yields of this magnitude can be obtained under widely different soil and climatic conditions found on the Island, provided moisture is adequate. For example, in experiments by Caro-Costas, *et al.* (*1*), properly managed Pangola grass yielded 23,207 pounds of dry matter per acre yearly on a steep Catalina clay in the mountain region. Nearby experimental Pangola grass pastures properly managed and heavily fertilized, yielded 900 pounds of gains in weight and 6,379 pounds of total digestible nutrients per acre yearly.

SUMMARY

The effects of nitrogen rates ranging from 0 to 1,600 pounds of N per acre yearly and of 30-, 45-, and 60-day harvest intervals on the yield and composition of Pangola grass were determined for 2 consecutive years.

Yields increased sharply with nitrogen fertilization up to the 400-pound level, while protein content increased up to the 1,600-pound level. About two-thirds of the fertilizer nitrogen was recovered in the forage when 400 pounds or less were applied per acre yearly. Efficiency of utilization, in terms of dry matter produced per pound of nitrogen, decreased with increasing rates.

Yields and lignin content of the forage increased while the protein content decreased with length of harvest interval.

A 45-day harvest interval during seasons of flush growth, and a 60-day interval during the season of slow growth, combined with 400 pounds of nitrogen per acre yearly seems to be the optimum combination. Yields varied widely with season of the year.

RESUMEN

Se estudió el efecto de aplicaciones de nitrógeno que variaban entre 0 y 1,600 libras por cuerda por año, y de intervalos de corte de 30, 45, y 60 días, en el rendimiento y composición de la yerba Pangola (*Digitaria decumbens*).

Los rendimientos aumentaron con niveles de nitrógeno hasta 400 libras por cuerda por año. El contenido de proteína aumentó con niveles de nitrógeno hasta 1,600 libras por cuerda por año. Se recuperó aproximadamente en el forraje las dos terceras partes del nitrógeno aplicado hasta

400 libras por cuerda. La eficiencia de utilización expresada en términos de forraje seco producido por cada libra de nitrógeno disminuyó según se aumentaban los niveles de nitrógeno.

Los rendimientos de forraje seco y el contenido de lignina aumentaron, pero el contenido de proteína disminuyó según se alargaron los intervalos de corte.

Un intervalo de corte de 45–60 días y 400 libras de nitrógeno por cuerda por año parece ser el tratamiento óptimo.

La producción varió considerablemente durante las distintas épocas del año.

LITERATURE CITED

1. Caro-Costas, R., Vicente-Chandler, J., and Figarella, J., The yield and composition of five grasses growing in the humid mountains of Puerto Rico as affected by nitrogen fertilization, season, and harvest procedure, *J. Agr. Univ. P.R.* **44**(1), 1961.
2. Engibous, J. C., Friedmann, Jr., W. J., and Gillis, M. B., Yield and quality of Pangola grass and Bahia grass, as affected by rate and frequency of fertilization, *Soil Sci. Soc. Amer. Proc.* **22**(5) 423–5, 1958.
3. Oakes, A. J., Bond, R. M., and Skov, O., Pangola grass in the United States Virgin Islands, *Trop. Agr.* **36** 130–7, 1959.

Effects of Two Cutting Heights on Yields of Five Tropical Grasses[1]

Rubén Caro-Costas and José Vicente-Chandler[2]

INTRODUCTION

The effects of fertilization, frequency of cutting, grazing versus cutting management, and of season of the year on yields and composition of the major grasses of Puerto Rico have been studied in considerable detail (*2,3,4,5*)[3]. However, the authors have found little quantitative data in the literature on the effect of cutting heights on productivity of these grasses. Caro-Costas and Vicente-Chandler (*1*) found that Napier grass cut to a height of 2 inches from the ground yielded more than when cut to a height of about 10 inches. Watkins and Lewy (*6*) reported that highest yields of Napier and molasses grass were obtained by cutting to a height of 6 to 8 inches, and of Guinea grass by cutting to a 12-inch height, but did not present data to substantiate these conclusions.

The purpose of the present study was to determine the effect of two cutting heights on the productivity of well-fertilized Napier grass (*Pennisetum purpureum*), Guinea grass (*Panicum maximum*), Pangola grass (*Digitaria decumbens*), molasses grass (*Melinis minutiflora*), and Para grass (*Panicum purpurascens*) mixed with some Carib grass (*Eriochloa polystachya*), under typical conditions in the humid mountains of Puerto Rico.

METHODS AND PROCEDURE

The experiment was carried out at Orocovis, which has a mean annual temperature of about 75° F., and a seasonal variation of less than 10° F. Annual rainfall was 77.8 and 60.0 inches for the first and second years of experimentation, respectively. The soil was Catalina clay, a deep, red, acid lathosol, on 30-percent slopes. The surface 6 inches had 4.5 percent of organic matter; a pH of 5.3; 16.5 m.e. of exchange capacity, and 10.4 m.e. of exchangeable bases per 100 gm. of soil; and a volume weight of 0.98 with 11 percent of the pores drained at a tension of 60 cm. of water.

[1] This report covers work carried out cooperatively between the Soil and Water Conservation Research Division, Agricultural Research Service, USDA, and the Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P.R.

[2] Agronomist, cooperative between USDA and the Puerto Rico Station, and Project Supervisor, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, respectively.

[3] Italic numbers in parentheses refer to literature cited, p. 49.

TREATMENTS

Grasses were cut: 1, Close to the ground (0–3 inches) and 2, high (7–10 inches from the ground).

Treatments were replicated five times for each grass, using plots 10 x 30 feet in size. All plots were limed to about pH 6.0 and received 3,000 pounds of 14-4-10 fertilizer per acre yearly in six equal applications.

TABLE 1.—*The effect of two cutting heights on annual yields and protein content of 5 well-fertilized tropical grasses growing in the humid mountains of Puerto Rico, and harvested every 2 months over a 2-year period, 1958–59*

Grass and cutting height	Yields of green forage per acre yearly				Yields of dry forage per acre yearly[2]		Protein[3]
	1958	1959	Average of 2 years[1]				
	Lb.	*Lb.*	*Lb.*		*Lb.*		*Percent*
Molasses							
high	67,802	53,973	60,887	**	12,056 (19.8)	**	13.5
low	33,959	5,104	19,531		3,945 (20.2)		13.5
Pangola							
high	72,993	86,507	79,750	**	19,937 (25.0)	**	11.5
low	126,440	121,829	124,134		29,296 (23.6)		12.1
Para							
high	89,030	81,142	85,086	**	19,740 (23.2)	**	11.0
low	122,612	88,740	105,676		24,728 (23.4)		11.0
Guinea							
high	105,357	102,543	102,950	**	25,223 (24.5)	NS	10.2
low	112,346	119,119	115,732		24,651 (21.3)		11.1
Napier							
high	147,233	103,592	125,412	**	23,201 (18.5)	**	10.3
low	191,545	125,280	158,412		27,880 (17.6)		9.2

[1] Asterisks indicate differences are statistically highly significant (0.01 level).
[2] Numbers in parentheses indicate percentage of dry matter.
[3] On a dry-weight basis.

The forage in all plots was harvested every 2 months by cutting to the prescribed height, and was weighed. Samples were taken from each plot once a year and their dry-matter and protein contents determined.

The experiment ran a full 2 years.

RESULTS AND DISCUSSION

Results are summarized in table 1.

Yields of molasses grass were severely reduced by close cutting. By the end of the first year this grass had almost diappeared from the plots cut close to the ground.

On the other hand, much higher yields of Napier, Para, and Pangola grass were obtained with close cutting. Yields of green Napier grass were increased 27 percent, of Para grass 25 percent, and of Pangola grass 56 percent by cutting close to the ground. Higher yields were obtained with low cutting at all seasons of the year with these grasses.

Cutting height had no apparent effect on yields of dry Guinea grass. However, high cutting seems more desirable since it resulted in a better stand, faster recovery after harvesting, and less weed growth. Slightly more total green forage was produced with low cutting, but the reverse occurred during some periods, probably due to seasonal effects on bud differentiation.

Height of cutting had no apparent effect on protein content of the grasses.

The sharp differences in yields caused by varying cutting heights are striking and show the importance of managing each grass in accordance with its requirements. For example, if molasses and Pangola grasses were compared with high cutting they would produce similar yields; if with low cutting molasses grass would yield little and eventually disappear, while if both grasses were cut at the best height for the species (*i.e.* close cutting with Pangola and high cutting with molasses) Pangola would yield about twice as much forage as molasses grass.

SUMMARY

The effect on the productivity and protein contents of well-fertilized Napier, Para, Guinea, Pangola, and molasses grasses harvested every 60 days for 2 years, of cutting close to the ground (0–3 inch) or to a 7–10 inch height, was determined under typical conditions in the humid mountains of Puerto Rico.

Yields of molasses grass were severely reduced by close cutting and the grass eventually disappeared from plots with this treatment. On the other hand, yields of Napier, Para, and Pangola grasses were increased 27, 25, and 56 percent, respectively, by low cutting. Although yields of Guinea grass were not strongly affected by cutting height, high cutting resulted in a better stand, faster recovery after harvesting, and less growth of weeds.

RESUMEN

Se estudió el efecto en el rendimiento de yerbas Napier, Pará, Guinea, Pangola y melao, de cortarlas a una altura de 0–3 y de 7–10 pulgadas del suelo cada 60 días durante 2 años.

Con corte bajo se redujo grandemente el rendimiento de la yerba melao. Sin embargo, los rendimientos de las yerbas Napier, Para y Pangola fueron marcadamente más altos con corte bajo. Aunque la altura de corte no

afectó grandemente el rendimiento de la yerba Guinea, con corte alto se mantuvo más vigorosa, recobró más rapidamente después del corte, y crecieron menos malas yerbas.

LITERATURE CITED

1. Caro-Costas, R., and Vicente-Chandler, J., Comparative productivity of Merker grass and of a Kudzu-Merker grass mixture as affected by season and cutting height, *J. Agr. Univ. P.R.* **40** 144–51, 1956.
2. Caro-Costas, R., Vicente-Chandler, J., and Figarella, J., The yields and composition of five grasses growing in the humid mountains of Puerto Rico, as affected by nitrogen fertilization, season, and harvest procedure, *J. Agr. Univ. P.R.* **40** 107–20, 1969.
3. Little, S., Vicente-Chandler, J., and Abruña, F., Yield and protein content of irrigated Napier grass, Guinea grass, and Pangola grass, as affected by nitrogen fertilization, *Agron. J.* **51** 111–3, 1959.
4. Rodríguez, J., Effect of nitrogen applications on the yields and composition of forage crops, *J. Agr. Univ. P.R.*, **33** 98–117, 1949.
5. Vicente-Chandler, J., Silva, S., and Figarella, J., The effect of nitrogen fertilization and frequency of cutting on the yield and composition of three tropical grasses, *Agron. J.* **51** 202–6, 1959.
6. Watkins, J. M., and Lewy-van Severin, M., Effect of frequency and height of cutting on the yield, stand and protein content of some forages in El Salvador, *Agron. J.* **43** 291–6, 1951.

Evaluation of the Averell and Norris Method for the Determination of Parathion in West Indian Cherry (*Malpighia punicifolia*, L.)

Gilberto García Monge[1]

INTRODUCTION

The synthetic insecticide O,O-diethyl O-(*p*-nitrophenyl) thiophosphate has acquired in the United States the generic name "parathion" and the commercial name of Thiophos 3422 insecticide. Pérez (*5*)[2] found that this insecticide controls the fruit weevil (*Anthonomus flavipes*) in West Indian Cherry. As this compound is toxic to warm-blooded animals, it is necessary to obtain data on crop parathion residue as a result of parathion treatment before definite recommendations for satisfactory pest control are made. In order to obtain these residue data it was decided to evaluate the Averell and Norris (*1*) procedure when applied to West Indian Cherry.

LITERATURE REVIEW

Gunter and Blinn (*4*) mentioned that in the composition analysis of parathion, this insecticide is determined by ultraviolet spectrophotometric examination ($\lambda_{max.}$ 274 mμ). In residue analysis the parathion must be extracted from the plant material. The parathion on the extract is mixed with other organic compounds found in plant material which will probably absorb in the ultraviolet region interfering with the absorption of parathion. It does appear that the nitro group in the parathion molecule offers the best approach to a colorimetric method. In the Averell and Norris method this nitro group is reduced to an amino group which is diazotized with sodium nitrite and coupled with N-(1-naphtyl)-ethylenediamine dihydrochloride to produce an intense magenta color ($\lambda_{max.}$ 555 mμ).

Wilson, *et al.* (*8*), described a modification of the original method of Averell and Norris for the determination of parathion in citrus oil. The benzene extract of plant material was used without any pretreatment and the quantity of sample required was drastically reduced. Isopropyl alcohol was substituted for ethyl alcohol.

Edwards (*3*) analyzed benzene samples from several manufacturers following the Averell and Norris procedure. He found an apparent parathion concentration ranging from 6.8 to 68.8 μg./200 ml. of benzene.

[1] Research Assistant in Chemistry, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P.R.

[2] Italic numbers in parentheses refer to Literature Cited, p. 53.

Spectro-transmittance curves for nitrobenzene and benzene showed the absorption maximum about 555 mμ which corresponds to a reduced and coupled parathion maximum. Inasmuch as c.p. benzene is the solvent recommended for stripping parathion residue from plant material, this solvent may constitute a common source of error.

Blinn and Gunther (*2*) made a spectral study of methyl anthranilate, a substance found in grapes. The methyl anthranilate hydrochloride was carefully purified and subjected to the exact reducing, diazotizing, and coupling procedure used for parathion estimations (*1*). The absorption maximum for methyl anthranilate differs by only 8 mμ from the parathion maximum. It was shown that if methyl anthranilate is present in the plant material it interferes seriously in a determination for parathion by the above-mentioned procedure.

MATERIALS AND METHODS

Fresh West Indian Cherries were ground in a Waring Blendor. Two-hundred-and-fifty-gram samples of the pulp were weighed in duplicate and fortified with known concentrations of parathion ranging from 0 to 2.4 p.p.m. of parathion in benzene. The samples were mixed with 500 gm. of benzene and extracted as described previously by Roldán (*6*). Two hundred and fifty grams of the benzene extract were weighed into a 300-ml. tall-form beaker and decolorized with 11 gm. of a mixture of Attapulgus Clay and Hyflo Super-cel, using a batch method rather than the column method described by Averell and Norris. The clay-Hyflo Super-cel mixture was never allowed to dry during the process of filtration and washing with benzene.

The decolorized benzene solution was concentrated to 10 ml. in a 300-ml. tall-form beaker on a steam bath. The last 10 ml. of benzene were removed at room temperature by passing air over the surface, evaporation being discontinued as soon as the residue was dry. This residue was dissolved and the color developed as described by Averell and Norris (*1*). The spectro-transmittance curve determined in a Coleman Universal Spectrophotometer, Model 14, showed an absorption maximum at about 555 mμ. The standard transmission-concentration curve was prepared by using a stock solution of parathion in benzene. A blank solution, consisting of 10 ml. of benzene with no parathion, was used to set the spectrophotometer scale at 100-percent transmittance. A straight-line relationship was obtained by plotting milligrams of parathion against percentage transmittance. The same kind of relationship was obtained by Averell and Norris (*1*) as well as by Santini and Sotelo (*7*).

Under the experimental conditions adopted in these systems the meas-

ured concentrations in the Coleman Spectrophotometer are believed to be reliable in 0.1 p.p.m.

RESULTS AND DISCUSSION

Table 1 presents the results obtained by the Averell and Norris procedure in the recovery of parathion from West Indian Cherry. The corrected parathion concentrations were obtained after subtracting the apparent parathion concentration of benzene from each sample. Edwards (*3*) recommended a distillation for removal of interfering substances found in benzene. This procedure is more expensive, time-consuming, and hazardous that the above-mentioned procedure under the experimental conditions adopted in these systems.

TABLE 1.—*Recovery of parathion from fortified West Indian Cherry*

Sample No.	Parathion Added	Apparent Parathion Concentration	Corrected Parathion Concentration	Recovery
	P.p.m.	*P.p.m.*	*P.p.m.*	*Percent*
1	0.2	0.46	0.18	88
2	.4	.62	.34	8
3	.8	.96	.68	85
4	1.0	1.18	.90	90
5	1.4	1.48	1.20	86
6	2.4	2.03	1.75	73
7[1]	0	.26	—	—
8[2]	0	.28	—	—

[1] West Indian Cherry without fortification.
[2] Solvent alone (benzene).

From table 1 the following conclusions can be made:

1. Satisfactory recovery of parathion was obtained from the West Indian Cherry. The average recovery was 85 percent.

2. Benzene used as a solvent in the Averell and Norris (*1*) procedure for the determination of parathion developed a magenta color which absorbs in the same spectral region of the color developed by parathion. This was previously observed by Edwards (*3*) and explained as being due to nitro or amine aromatic groups present as impurities in benzene. During the procedure the benzene extract is concentrated 25 times causing also a concentration of the impurities.

3. West Indian Cherries contain no interference background when analyzed by the Averell and Norris procedure for parathion. Therefore, the Averell and Norris method can be employed satisfactorily for the analysis of parathion residue in West Indian Cherry.

SUMMARY

This paper presents the results obtained in studies carried out in the evaluation of the Averell and Norris procedure for parathion determinations as applied to the West Indian Cherry. The data obtained showed that the samples need to be corrected for the interference effect of the solvent, benzene, which contains an appreciable apparent concentration of parathion. West Indian Cherries offer no interference background to the above procedure. Therefore, satisfactory residue data can be obtained for the West Indian Cherry by the Averell and Norris method.

RESUMEN

Se presentan los resultados obtenidos en estudios hechos en la evaluación del método de Averell y Norris en acerola. Los resultados demuestran que las muestras tienen que corregirse para una interferencia en el solvente, el cual contiene una cantidad aparente de paración. La acerola no contiene niguna substancia que interfiera en el método descrito.

Por lo tanto, se pueden obtener resultados satisfactorios para residuos de paración en acerola usando el método de Averell y Norris.

LITERATURE CITED

1. Averell, P. R., and Norris, M. V., Estimation of small amounts of O,O-Diethyl O-(*p*-Nitrophenyl) Thiophosphate, *Anal. Chem.* **20** 753–6, 1948.
2. Blinn, R. C., and Gunther, F. A., Interference of methyl anthranilate in estimation of parathion, *Anal. Chem.* **22** 1219, 1950.
3. Edwards, F. I., Jr., Source of error in estimating small amounts of parathion. *Anal. Chem.* **21** 1415, 1949.
4. Gunther, F. A., and Blinn, R. C., Analysis of Insecticides and Acaricides, Interscience Publishers, Inc., pp. 505–7, New York, N.Y., 1955.
5. Pérez, M., Department of Entomology, Agricultural Experiment Station of the University of Puerto Rico, personal communication.
6. Roldán, J., Parathion residue studies on acerola, *J. Agr. Univ. P.R.* **43** 147–51, 1959.
7. Santini, Jr., R., and Sotelo, E., Determination of O,O-diethyl O-*p*-nitrophenyl thiosphosphate (parathion) in pineapples, *J. Agri. Univ. P.R.*, **39**(1) 12–5, 1955.
8. Wilson, C. W., Barer, Rodger, Genung, Dale, and Mullow, James, Estimation. of O,O-diethyl O-(p-nitrophenyl) thiosphosphate, *Anal. Chem.* **23** 1487–9, 1951.

AGRICULTURAL EXPERIMENT STATION

(*Continued from inside front cover*)

Station Staff[1]

Central Analytical Laboratory

Riera, B.S., Chemist in Charge
Fernández (Miss), M.S., Analyst in Chemistry
Igaravídez, B.S., Associate Chemist
Julia de Lorenzi (Mrs.), B.S., Analyst in Chemistry
Lebrón Monclova, B.S., Analyst in Chemistry
M. Peña Ramírez (Mrs.), B.S., Analyst in Chemistry
Rivera Núñez (Miss), M.S., Assistant Chemist
Villafañe Colom (Mrs.), B.S., Analyst in Chemistry

Library

P. Hayes (Miss), M.A., Librarian

Office of the Editor

Molinary Salés, B.S., Agronomist and Technical Editor
Swann Harding, B.S., English Technical Editor

Cooperative ARS Research Project[4]

Vicente Chandler, M.S., Supervisor Cooperative Research Project ARS
Abruña, M.S., Soil Scientist
Figarella, B.S., Soil Scientist
Caro Costas, B.S., Assistant Agronomist in Soil Conservation

Rum Pilot Plant

Rodríguez Benítez, M.S., Technical Director
Aguilera Flores, B.S., Assistant Chemist
Belardo Yadós[2], B.S., Assistant Chemist
M. Brau, Ph.D., Chemical Engineer
Calderón Tomei, M.S., Assistant Bacteriologist
M. Camacho (Miss), B.S., Assistant Chemist
García Morín, Ph.D., Chemist
M. de Mariani (Mrs.), M.S., Assistant Chemist
Montalvo, B.S., Research Assistant
Sánchez (Miss), B.S., Research Assistant

School of Medicine

F. Asenjo, Ph.D., Biochemist
Ramírez Vergara, B.S., Research Assistant
Torres (Miss), B.S., Research Assistant
Recio (Miss), B.S., Research Assistant

Service Department

C. Guevara, M.S., Agronomist and Administrative Assistant, Head of Department
J. Rigau, B.S., Assistant Agronomist
Rivera López, B.S., Associate Agronomist

Statistical Section

Cruz Miret, B.S., Assistant Agronomist
L. Navas Elías (Miss), B.S., Assistant Statistician

Substations and Seed Farms

Main Office Seed Farm Division

G. Moscoso, M.S., Horticulturist, Head of Division
Ferrer de Comas (Mrs.), B.S., Research Assistant
Meléndez González, B.S., Associate Floriculturist

Gotaher Substation

J. Rodríguez[2], M.S., Assistant Agronomist in Charge
Bosque Lugo, B.S., Assistant Agronomist in Charge (Acting)

P. L. Meléndez, B.S.A., Research Assistant
A. Morales Muñoz, B.S., Research Assistant
R. Pérez Pérez, B.S., Research Assistant
A. Torres Sepúlveda, B.S., Research Assistant

Corozal Substation

A. Rodríguez Cabrera, M.S., Associate Agronomist in Charge
R. Gandía Caro, M.S., Assistant Agronomist
G. Parés Reyes, B.S., Research Assistant
A. Ramos Vázquez, B.S., Research Assistant
P. Suazo, B.S., Research Assistant

Isabela Substation

A. Riollano, M.S., Agronomist in Charge
R. Abrams, M.S., Assistant Plant Breeder
J. Badillo Feliciano, B.S., Research Assistant
O. Crespo López, B.S., Research Assistant
E. González Villafañe, B.S., Research Assistant
L. B. Ortiz, M.S., Associate Agronomist and Administrative Assistant
A. Pérez, M.S., Research Assistant
C. Ramos Caro, B.S., Research Assistant

Lajas Substation

A. Eschenwald-Hess, M.S., Agricultural Engineer and Associate Professor in Charge
L. Almodóvar Vega, M.S., Research Assistant
I. Carlo, M.S., Assistant Animal Husbandman and Assistant Professor
F. Díaz Irizarry, B.S., Assistant Engineer
J. García Albino, B.A., Research Assistant
R. Irizarry, B.S., Assistant Agronomist and Administrative Assistant
M. J. Martínez, B.S., Research Assistant
R. Mendoza Barbosa, B.S., Research Assistant and Instructor
J. Ortiz Vélez, M.S., Assistant Drainage Scientist
J. Oliver Campos, B.S., Assistant Professor, In Charge of Laboratory
E. Pérez Rivera, B.S., Research Assistant
M. Pérez Zapata, B.S., Research Assistant
J. A. Quiñones, B.S., Research Assistant
A. Ramírez Ortiz, B.S., Research Assistant
M. Rico, M.S., Assistant Horticulturist
M. Rojas Daporta, M.S., Animal Husbandman
G. Rosado Carbó, V.M.D., Associate Veterinarian
J. H. Sanfiorenzo, M.S., Assistant Animal Husbandman
F. Silvestry, B.S., Research Assistant
J. Torres Más, M.S., Research Assistant
R. Vázquez, M.S., Assistant Irrigation Scientist

Gurabo Substation

M. A. Lugo-López, Ph.D., Assistant Director in Charge
A. Acosta Matienzo, M.S., Research Assistant
J. E. Barbosa, B.S., Research Assistant
E. G. Boneta, B.S., Research Assistant
M. Capiel, M.S., Assistant Soil Scientist
C. González Molina, M.S., Assistant Plant Breeder
L. López Matos[2], M.S., Assistant Pathologist
M. A. Manzano, B.S., Assistant Biochemist
C. Ortiz Lugo, B.S., Associate Agronomist and Administrative Assistant
E. Reyes Soto, B.S., Research Assistant
A. Sierra Bracero, B.S., Research Assistant
J. Vélez Santiago, B.S., Research Assistant

Fortuna Substation

C. J. Clavell, B.S., Associate Horticulturist in Charge
G. C. Jackson, M.S., Assistant Horticulturist
J. López García, B.S., Research Assistant

---

[1] As of July 1, 1960.
[2] On other types of leaves.
[3] On leave to pursue studies.
[4] USDA collaborators.